Journal
of the
British Interplanetary Society

Vol. 10, No. 4 **XLI** **JULY, 1951**

THE JOURNAL

Every editor is all-too-familiar with the fact that it is impossible to please all the readers the whole of the time. In the case of a publication such as this *Journal*, the problem is one of quite exceptional difficulty. We receive complaints that it is not technical enough—or alternatively that it is so technical that no-one can understand it. The last point was made in a letter which we recently received from a new member, who felt that the amount of material in the B.I.S. *Journal* which he could understand was so small that it did not justify continuance of his subscription. The letter raised a number of points in connection with *Journal* policy and we think that a few editorial comments may prevent misunderstandings and make clear our aims.

The object of the B.I.S. is to advance the progress of astronautics, and its most important duty is therefore the publication of technical papers in this field. It is upon these papers, in fact, that the prestige, and hence the influence, of the Society largely depends.

Because astronautics covers such an unusually wide range of subjects, not even the most erudite of our Fellows can hope to understand all the technical articles published—or even half of them. In Volume 9, for example, there were papers on medicine, air-conditioning, structural engineering, thermodynamics and rocket design. There must be very few people indeed who have much knowledge of more than two of these. The non-technical Member should not feel, therefore, that any particular Fellow is so *very* much better off than he is!

During the course of the year, we try to make as "balanced" a volume of the *Journal* as possible, though there may be individual issues which are almost wholly specialised. An analysis of Volume 9 shows that 52 per cent. of its contents was non-technical and hence intelligible (though not necessarily interesting!) to anyone who cared to read it. About 13 per cent. was "borderline" and only 35 per cent. was completely technical.

One day, when astronautics has reached a more active stage, there will be room for two kinds of journal—a "popular" one which will be of general interest and a specialised publication for the experts. But for the moment, and for some time to come, the *Journal* has to serve all purposes.

The steady increase in membership, and above all the satisfactory rate of renewal of subscriptions, seems to indicate that there is general agreement on this policy and that the reasons for it are understood. We can only hope that even if many of our members find that much of the *Journal* is beyond them, they will nevertheless continue to give us their support. Space-travel can only be achieved by the united efforts of many kinds of men, in many lands—and they will not all be scientists or engineers.

THE FIRST TASK OF AN INTERNATIONAL FEDERATION— AN INSTITUTE FOR ASTRONAUTICS

By Dr. G. Loeser*

Hardly any problem exists that involves the cooperation of so many different branches of science and technology as space-travel. It is futile to argue *which* branch is the most important, for we cannot ignore a single one.

Even if any doubt still existed as to the enormous scale of the work space-travel will require, and the costs and effort it will need, this should have been dispelled by Dr. Sänger's paper "The Cost of Space Travel."† It is quite clear that this huge task cannot be performed by a single country, and can only be attained by loyal and unselfish international cooperation.

It must not be forgotten that the number of people aware of the greatness and responsibility of the task is still small. Nor must we overlook the fact that there is a much larger number of people who—logically enough in view of the recent past—regard the rocket as a weapon only. No wonder that in this situation the national astronautical groups are often believed to be hopelessly optimistic visionaries.

These groups—unlike the established scientific societies with their traditions—have the duty not only of dealing with scientific and technical problems but also of rousing public interest by lectures, exhibitions, radio, etc., informing the public that rockets are not purely death-dealing weapons but that their inventors wished to see them used peacefully for space-travel. The groups must exert all their influence in order to spread this idea in an objective and sober way. Rash and utopian fantasies will endanger confidence in the reality of the desired aim and may even destroy the rise of this confidence.

The idea that international cooperation is essential to secure our aim is not new. Even from the beginning the first astronautical associations tended to work with those in other countries. Publications and results were exchanged, and occasional visits took place. To-day, however, we have entered a phase when these loose contacts based on the personal initiative of a few people are insufficient. To judge from the unanimity with which the delegates at the Paris Congress approved the resolution to form an international federation, the idea has now become common property among the national societies. This leads us to hope that the Second International Congress in London, the preparations for which have been handed over to the B.I.S., will result in the founding of the projected federation.

Even assuming that the national groups will be able to gain much greater support, federal cooperation will not by itself enable us to realise our aim in an appreciably nearer future. The most urgent task of the Federation is therefore that of finding ways of accelerating progress.

Such a way—perhaps the most promising—would be the foundation of an International Institute for Astronautics under the management of the Federation. Such an institute should be set up—even if on the most modest scale—

* This paper is submitted as a basis for discussion at the London Congress, September, 1951.

† Inauguration lecture, delivered at the 4th Annual Meeting of the G.f.W. in Stuttgart, 1951.

as soon as the Federation can find the means—either through the national groups or in any other way.

The objection that such an institute would be only a shadow compared with the existing military research establishments is not valid. In the first place it is possible—even if unlikely—that political events may result in a complete stop of military research. Secondly, any astronautical work carried out by War Departments will be primarily for military purposes, and only incidentally will it be used for scientific research. (As indeed has happened at White Sands with V.2; though we must be grateful to the American military authorities for placing these rockets at the disposal of scientists, it must be remembered that the long-term objective was to obtain information for the building of better weapons.)

As we are unable to foresee the future progress of events, I am absolutely convinced that an international institute for astronautics, dealing with the problems of peaceful space-travel, will be of the greatest importance.

Let us suppose that the resources provided for this Institute by the Federation are insufficient for effective practical work, so that its activities are restricted to theoretical studies. As evolution can neither be stopped nor kept back, some day the United Nations, a World Parliament or some other international institution will take up the problem, working for peaceful space-travel as a common aim of civilisation. It is obvious that the achievement of this aim could not be through the medium of any nation's War Department. Certainly the results of military research would be used, but the actual work must be done by some international institution. It would, however, be absurd to set one up if it was already in existence in the shape of the International Institute for Astronautics. It is the Federation's duty to build up this Institute so that it may become the nucleus of a larger organisation, which will be capable of taking over the tasks of astronautics when the time comes to do so.

Many may think these speculations optimistic and remote from political reality. In one way, however, they are quite realistic. Despite the sad experience of the past, it is still possible that the politicians may be able to achieve world peace through common sense and humanity. In this case, all the above ideas would be neither utopian nor excessively optimistic. And if political events continue to be ruled by stupidity—which can only result in self-destruction—then the idea of peaceful space-travel will become futile and meaningless anyway. Thus as long as we hope for the realisation of space-travel, we have no alternative but to be optimists.

If no other alternative exists, it should be possible to set up the Institute on a modest basis and to finance it by the groups which are members of the Federation. However, it cannot be expected that the modest means of these groups would permit of any large-scale practical work. Of course we may attempt to secure donations for the Institute, though the time for large gifts for idealistic purposes seems to be past. In any case both these methods must be regarded as first expedients since they are inadequate to the task.

The Federation would be much more effective if it joined a larger organisation —one, of course, with a peaceful aim. The only body at present meeting these requirements is the United Nations. It remains to be seen if the Federation,

in any form, can be placed under the patronage of UNO. The first step would be to contact the International Council of Scientific Unions set up by UNESCO. Membership of this Council would open up two ways of financing the Institute for Astronautics. In the first place, after a precise statement of aims and objects, an attempt might be made to obtain support from UNESCO. On the other hand, profit might be taken of the fact that each national group which is a member of the International Federation for Astronautics will automatically be a member of UNESCO as well. For the individual groups, this fact might facilitate the obtaining of credits from the governments of their respective countries. As soon as one national group has obtained such aid from its government, this will set a precedent for others.

As the member states of UNO pay their fees according to a fixed scale and part of these fees is handed over to UNESCO, it is possible that UNESCO might budget for an annual amount for the Institute.

The difficulties which will have to be overcome to provide the means for an active and productive international institute for research must not be underrated. On the other hand, we must not allow ourselves to be overwhelmed by them. The results already obtained thanks to goodwill and idealism should encourage us to begin this task as soon as the Federation is formally constituted.

ASTRONAUTICS AT THE CINEMA

By A. V. Cleaver

One school of thought tends to despise the cinema, associating it irrevocably with cheap sentimentality, superficial glamour, and a means of providing the masses with second-hand emotion and adventure while they variously hold hands in the dark or chew endless quantities of peanuts and ice cream. In opposition to this conservative group of the "intelligentsia" (ever loyal to the Old Vic, and anything to do with the legitimate stage), there are the Hampstead highbrows, stoutly acclaiming the film as the greatest possible art-form. This writer is inclined to agree that perhaps 90 per cent. of the output of the world's film studios richly deserves the former judgment, while at least part of the remainder shows promise of justifying the latter.

At all events, it is with the second, more hopeful, view that we are concerned here. The power of the film to transcend all limitations of space and time, its ability to depict with realism any actual or imaginary scene or event, has a peculiar value for astronautical themes—especially at the present time, a generation or so before the complete realisation of space-travel. No book, play, or painting could convey the idea of what space-flight will really be like so nearly as accurately or graphically as a moving picture in sound and colour made with all the skill of a large "special effects" department.

There is another aspect, too; almost everyone goes to the cinema nowadays, at least occasionally, and the screening of a new film therefore attracts a great deal of attention on a national scale. This ranges from the privately-expressed opinions of all classes of individuals to the public comment of the critics of press and radio. Thus, an astronautical film gives those of us who are already

active in the interplanetary movement an excellent opportunity of learning what the lay world thinks about it.

Towards the end of last year, there were abundant signs in London, and elsewhere in England, that we were about to be presented with such an opportunity in quite a big way. Advertisement hoardings and neon signs began to depict sleek and deadly rockets trailing sheets of flame across the heavens; tin models of similar character appeared on the roofs of various local entertainment palaces; self-conscious men in space-suits (of varying degrees of plausibility) were to be encountered walking the streets of certain British cities; some cinema managers displayed a surprising desire to co-operate with New York's Hayden Planetarium in its own publicity stunt of accepting "bookings" for interplanetary voyages to take place at an unspecified future date, or else organised "Quiz" competitions for the best set of answers to a sort of astronautical catechism; all kinds of organisations—including a few incongruous ones, such as our sedate British Railways—showed a tendency to climb on to the currently-fashionable advertising bandwaggon ("Excursions to the Moon? Not yet—but when, etc.").

Disregarding that small part of all this endeavour which was directed towards promoting the serialistic adventures of Flash Gordon on the screens of certain news-reel theatres, most of it was of course in support of two films—"Rocketship XM" and "Destination Moon" (see B.I.S. Journal, Sept., 1950). Only the latter was to be taken seriously in any technical sense (or, for that matter, as a piece of film making), but both served as some sort of astronautical barometer for public opinion, and as a stimulant to increase popular interest in our subject. Reports from Holywood indicate that, in parallel with the present American boom in book and magazine science-fiction, a great number of further interplanetary epics are now on their way to us from the film studios. (Literally dozens—"When Worlds Collide," "The Man from Planet X," "The Thing," etc., etc.). One anticipates this onslaught with very mixed feelings, especially since many of the films in question are believed to be what the trade calls "B-pictures." This adjectival use of the second letter of the alphabet merely labels the production as one made on a small budget to be a second feature—but the net effect is often much the same as would be implied by the colloquial British usage.

However, the box-office success of the two full-length interplanetary pictures already shown suggests that Hollywood's commercial instinct is still sound. (Regrettably, there are no reports as yet of any serious astronautical interest on the part of British producers: a pity—the subject would be a "natural" for Powell and Pressburger.) *The Picturegoer* said that "Rocketship XM" (a "B-picture") grossed over a million dollars in the States, and broke Bank Holiday records at the London Pavilion. General Film Distributors, who handled "Destination Moon" in this country, told us that it took more money at the Leicester Square Theatre than any shown there in the preceding three months (and the film before it had been Somerset Maugham's "Trio"). Subsequently, they wrote after the general release that it was "one of our biggest grossers of 1950—it is in fact only slightly behind "The Blue Lamp," our number one box-office hit this year."

Prominent members of the Pacific Rocket Society getting the feel of space-travel on a visit to the "Destination Moon" control cabin set. E. G. Ewing (upper berth) and E. V. Sawyer (lower berth).

From our point of view, it was to be regretted that some cinemagoers failed to distinguish between the high technical accuracy of "Destination Moon" and the very different background of "Rocketship XM." A few, in fact—especially among the fair sex—even preferred the latter, allegedly on the grounds of its "greater human interest." I personally overheard a girl say of it, to her friend: "Coo, Doris, ain't it exciting—*ever* so much better than the one what we saw the other week." On the other hand, one's conversation with most people showed that they greatly appreciated the more authentic atmosphere of "Destination Moon"—film producers would do well to realise that most

Robert Heinlein (who wrote the story), Chesley Bonestell (who designed the sets) and Dr. R. S. Richardson (who, as one of the Mount Wilson and Palomar astronomers, provided some technical advice), seen on the "Destination Moon" lunar set. All are members of the B.I.S.

people now have at least a smattering of scientific knowledge, and that a very large section of the populace is actually engaged on one sort or another of technical work. In any case, one can see no valid reason why a film on some scientific theme should not be both technically accurate *and* dramatically satisfying at the same time—if its makers are prepared to take the necessary trouble.

The B.I.S. co-operation with the distributors of "Destination Moon" enabled us to sample a very fair cross-section of its reception by various classes of audience; we also paid very careful attention to the dozens of review notices conscientiously sent in to us by our press-cuttings agency. It was quite fascinating to compare the reactions of different types of audience.

Our first viewing was at a trade show, where film renters received it very favourably and quite seriously in an appreciative silence—save for a quiet chuckle, which one felt to be not wholly unsympathetic, at the sequence where a lunar territorial claim was made. At a subsequent showing for the London film critics, this same sequence was received with riotous laughter and some derisive applause; almost without exception, it earned unfavourable comment when the notices were written up. At the public showing of the film in London's West End, the reaction to this scene was much more restrained (about like that of the renters), while suburban and provincial audiences mostly received it without any demonstration of feeling. They appeared to take the future claiming of the Moon for granted, as being just as natural as Amundsen's

planting the Norwegian flag at the South Pole, just anticipating Scott's attempt to do the same thing with the Union Jack.

Conversely, however, the suburbs and provinces seemed to find it immensely funny when an experimental atomic rocket engine was said to have operated for an hour and forty minutes before it blew up. Other audiences seemed to accept this statement without amusement, apparently realising that deliberate tests to destruction are a normal part of engineering development, and that this particular one would have been quite an overload run for a device required to operate continuously only for minutes at a time.

Without exception, one found that all audiences reacted with uneasy laughter to the scenes depicting "free-fall" conditions in the spaceship cabin—rather in the way in which we all tend to laugh nervously at the actual discomfiture of someone else, when we realise it *could* happen to us, too. Also without exception (and without any astronautical significance, either!), they laughed when the credit title for Rip van Ronkle (one of the script writers) appeared on the screen.

One can sense, in an undefinable way which nevertheless carries conviction, the general feeling of any large group of people sharing a common experience—for example, the reactions of an audience watching a film or a play. On this count, we would say that all the "Destination Moon" audiences, whether they wanted to or not, caught the wonder of the scenes out in space and on the lunar surface, the tense excitement of the take-off, and the realisation that, when this thing was really done, history would have been made. Many personal comments made to us afterwards, often by complete laymen in the subject of astronautics, provided abundant proof of this assertion, and justified our belief that this serious film succeeded in its ambitious aim.

So also did just a few of the critics' reviews—but in general we feel quite sure that these were very unrepresentative of the public reaction in this country to "Destination Moon." The film trade press, in the main, received the production very favourably, as also did the technical periodicals (*Flight* headed their review: "Hollywood Makes Amends"). In the provinces, most of the press notices were enthusiastic, though few of them showed any signs of understanding the larger implications of the subject. Instead, they concentrated on the aspect of *physical* adventure in space-flight, and told their readers to go and see the picture because it was virile and exciting and new. Since this point of view, though limited, is entirely valid, we can have very little quarrel with it.

We admit, however, to feeling more inclined towards impatience with the London critics. Anyone who has ever attended any B.I.S. meeting will know that we are quite capable of laughing at astronautics—more so than most, we think, because we understand it better than most—but it is still hard to be tolerant with the type of mind that dismisses any new subject without trying to understand it, or even pausing to consider whether there is anything in it worth understanding. Such commentators invariably receive their just deserts from posterity, which can enjoy a good laugh at *their* expense—aeronautics provides a hundred examples, and astronautics will provide many more.

Most of the film critics on the national dailies were obviously interested, in

the main, in showing how witty and sophisticated they were. Even the ones who reviewed "Destination Moon" favourably were mostly unable to refrain from condescension, though *The Times* did begin its review with "Since it is as sure that man will eventually reach the moon as that he will run a mile in four minutes, it is surprising that the cinema has for so long been content to leave the whole affair to children's films." The *Daily Herald* said: "This is wonderful boys'-own stuff," the *Graphic* thought the film "will delight both small and big boys," and the *Sunday Chronicle* was pleased that it "gives us, at last, what children of all ages have never ceased to cry for—*viz.*, the moon." Dilys Powell in the *Sunday Times* was relieved to find the Moon "in lovely Lunicolor," while her nearest rival for normally intelligent film reviewing (C. A. Lejeune in *The Observer*) commented—with some reason, we concede (!) that—"Students in years to come will be surprised to learn that the first successful trip to the moon was financed by American business men as the result of watching a Woody Woodpecker cartoon." R. A. Young in *Punch* was also struck by this aspect of interplanetary promotion; after describing the film as "all a bit juvenile, perhaps," he concluded, "if the idea of sending a rocket to the moon can only be sold to a lot of hard-headed business men through the medium of a Woody Woodpecker cartoon, as it appears from this picture, perhaps we need not be so shy about being a little juvenile after all."

Few of the critics could forget their apparent Americophobia; one said, "America claims the planet. It can keep the picture, too, as far as I'm concerned." Another thought the Moon was made out to be "A sort of Formosa of the firmament," and a third, after describing the "Big laugh" which came "when the scientists formally annexed it for the U.S., apparently to prevent Russia using it as a bomb base to destroy the Earth," dismissed the whole film as "Pure Moonshine." To the best of our recollection, the actual dialogue in this controversial sequence was to the effect that Dr. Cargraves (the scientist on the expedition) claimed the Moon "in the name of God, on behalf of the United States, and for the benefit of all Mankind," so that some of the accusations implied (of purely American imperialism) were not entirely justified. The *Catholic Herald* deprecated the "rather pretentious 'stars and stripes' piety," and the *Daily Worker* naturally left God out altogether, but otherwise got the quotation right and generously described the picture as "intriguing good fun." However, they resented its suggestion that "the Government always turns to private enterprise when they're in a jam."

Finally, Miss Virginia Graham deserves a mention, for telling her readers in *The Evening Standard*, with sweeping authority, that "This is quite the silliest film I have seen in years. If I were a boy of 10 I should love it." She evidently has no great opinion of small boys, because she followed up this review with another, in *The Spectator*, which began "For those who like brilliant absurdities 'Destination Moon' will be a delight." Somewhat superfluously (we think), Miss Graham proceeded to the disdainful statement "—but then, I am not very progressive."

Yes, dear—we can see you're not. But we still think there's hope for us, because so many small boys *are*, with the merit of possessing receptive minds and a spirit of adventurous curiosity—whatever their other undoubted shortcomings.

BIOLOGICAL PROBLEMS OF SPACE FLIGHT

A Report of Professor Haldane's lecture to the Society on April 7, 1951

An informal talk, which was not only most interesting but also witty and highly entertaining, was given to the Society on April 7 by Professor J. B. S. Haldane, who was good enough to prepare it at very short notice to take the place of a promised paper by Professor J. D. Bernal on *"The Evolution of Life in the Universe."* Professor Haldane decided to speak on *"Biological Problems of Space Flight,"* saying that he considered it the duty of another London University Professor to step into the breach with an address on some nearly related subject.

Space flight, said Professor Haldane, raised three sets of biological problems:

(1) how would man live in a space-ship,
(2) how would he live on another planet, and
(3) what kind of life would he expect to meet there.

Curiously enough, it was harder to answer the first two questions now than twenty years ago. Much of the information was now secret, while a lot of misinformation has been circulated by science fiction writers.

Here Professor Haldane momentarily went outside his subject to suggest a possible future application of atomic power to rocketry: whereas plutonium would only explode when collected into a mass of the order of 10 kg., some element not yet discovered, *e.g.*, that of Atomic Number 102, might be found with a critical mass of less than one milligram, so that a series of small explosions could be used as a source of energy.

The chief dangers to the ship's crew were listed by him as: (*a*) acceleration, (*b*) meteorites, (*c*) solar heat, (*d*) other solar radiations, (*e*) suffocation, (*f*) starvation and thirst, and (*g*) harmful radiations from an atomic power plant.

Accelerations should not be excessive, but when acceleration stopped there would be a sensation of falling. "Presumably one might get accustomed to it," said Professor Haldane, but it might render sleep remarkably difficult. He would, however, prefer this to the alternative of rotating the ship to provide a substitute for gravity, as the latter, he thought, would raise difficulties in navigation.

The position as to meteorites had altered for the worse owing to the discovery by Whipple of "micro-meteorites" which do not flare up to become visible in our atmosphere, but whose presence is revealed by radar observations. Although these objects might not penetrate the metal skin of the ship, their contact with the windows might prove awkward.

Professor Haldane then discussed the effects of the sun's heat. A good deal of the more dangerous of the ultra-violet radiations are stopped by glass but, nevertheless, he did not recommend the crew to go too near the windows without wearing dark glasses. The danger is much increased when solar flares are in evidence, so it might be advisable to make space voyages during periods of minimum solar activity.

Respiration has always been a subject of special study by Professor Haldane, who usually acts as his own guinea-pig, so he had much to say about it. A man at rest uses up half a cubic foot of oxygen per hour, or one cubic foot when doing light work. The volume of carbon dioxide he gives out is 80 or 90 per cent. of the volume of oxygen used up, the exact percentage depending on what he has been eating. Thus, 50 cubic feet of oxygen would last him two days, or longer if he is inactive; this amount could be compressed into half a cubic foot for storage. Reckoning the oxygen by weight, half to one kg. of oxygen per day would be needed, so that one ton would last three men for more than a year. Such a quantity of oxygen would be best stored in liquid form, the storage vessel consisting of three flasks, one inside the other.

A convenient way of absorbing carbon dioxide by means of soda lime is to force through the solution a jet of oxygen carrying ten times its volume of air. If weight is the most important consideration, the best absorbent of carbon dioxide would be lithium oxide, but it is less efficient than soda lime. Potassium peroxide is another effective absorbent, with the added advantage of providing a source of fresh oxygen, but Professor Haldane said he did not approve of it.

Food supplies would in any case weigh more than the oxygen. They would have to be carried in a dry form and wetted before eating. The best plan to maintain a supply of water would be to remove it from the air by refrigeration, and from the crew's excretions by distillation.

Both food and oxygen supplies could be continually renewed by making use of the photosynthetic activity of plants. For this purpose Professor Haldane recommended keeping algae in a tank, through which one would bubble carbon dioxide in intense sunlight. It would be necessary to breed some species of edible algae which could live on sunlight and human excretions. This would make a balanced system, but it would only operate satisfactorily fairly near to the sun and would not do for longer voyages, say to Neptune or beyond.

One especially critical question is: will the ship leak? If there is the slightest leakage all the nitrogen and much of the oxygen would eventually be lost. In view of this danger, it would be best to live under the lowest possible atmospheric pressure, which, as Professor Haldane explained later on, would be one-quarter of a normal atmosphere.

Regarding the weight of shielding needed for protection against atomic radiations or cosmic rays, it might be necessary to compromise; to increase the probability of a successful completion of the voyage, it might be considered worth while, on balance, to save some weight and thereby increase the risks to the crew of exposure to harmful radiations.

Man's attempt to live on other heavenly bodies would be attended by various unfamiliar physiological effects; for instance, on an asteroid he could make not merely a high jump, but an infinite jump. On Mars, the reduced gravitation might cause him to wake from sleep with an uncomfortable falling sensation. And as a protection from radiations other than heat, an ultra-violet-proof glass visor might have to be worn.

No other planets in the Solar System have a respirable atmosphere. However, life in a diving suit is not particularly uncomfortable; even now one

can buy such a suit in which it is possible to live for 8 hours, the carbon dioxide being absorbed.

However, low atmospheric pressures can cause trouble. At anything less than a quarter of a normal atmosphere, breathing even pure oxygen will not maintain life. The partial pressure of water vapour in the lungs is 47 mm. Hg., that of carbon dioxide 40 mm., and if this is subtracted from the pressure of one-fifth of an atmosphere, it only leaves 103 mm. Hg. to play with, which is equivalent to little more than one-eighth of an atmosphere. Therefore a pressure of at least one-quarter atmosphere is needed inside a space-suit.

Excessive pressure is also harmful. At three atmospheres pure oxygen is rapidly fatal, causing bronchitis and fits, while nitrogen becomes poisonous at 8 atmospheres, and ordinary air at 10 atmospheres. A suitable mixture of helium and oxygen, however, can be tolerated up to 16 or 17 atmospheres.

Coming to the question of life being found on other planets, Professor Haldane apologised for discoursing, as a mere biologist, on a subject upon which we had been expecting a lecture by a physicist. He mentioned three hypotheses:—

(*a*) that life had a supernatural origin,

(*b*) that it originated from inorganic materials, and

(*c*) that life is a constituent of the Universe and can only arise from pre-existing life.

The first hypothesis, he said, should be taken seriously, and he would proceed to do so. From the fact that there are 400,000 species of beetles on this planet, but only 8,000 species of mammals, he concluded that the Creator, if He exists, has a special preference for beetles, and so we might be more likely to meet them than any other type of animal on a planet which would support life.

The third hypothesis would require that some types of living organisms could survive in interstellar space and infect new spiral nebulae with life, which might, he thought, be possible.

The second was the most probable, in Professor Haldane's view, though he could not tell us what was meant by the term "life" beyond suggesting that, for one thing, it is a pattern of chemical reactions. Even the Milky Way might be alive in a sense, but, if so, it must be a very primitive organism, because it is composed of far fewer component parts than the number of molecules in a bacterium. If the Milky Way is itself "alive," therefore, it is probably quite stupid.

One reason in favour of the second hypothesis is that molecules of living substance all have the same type of asymmetry. Yet their looking-glass images would probably work just as well and might, in fact, be found to constitute living substances on Mars or Venus. In that case, we would find food on these planets inedible, except for the fats, whose molecules are symmetrical.

Discussing the possibility of life elsewhere having a different chemistry, Professor Haldane said that, on Jupiter, ammonia might replace water at a temperature of −52 deg. Proteins might be built up of different amino-acids

from those on the Earth, whose limited number may merely be the result of selection. For instance, there is one amino-acid, canavanine, which is so far only found in a single plant species on the Earth.

Where no oxygen is readily available, there is no possibility of living things making rapid movements; on Mars, for instance, animals may be as slow in motion as plants are on the Earth. Possibly an intelligent fungus lives there, cultivating lichens for its food. It might communicate by means of smells or tastes, and, having failed to get in touch with us, might conclude that we were unintelligent and might try to fight us with chemicals to dissolve the ship, our boots, etc. Personally, he thought that no mind resembling ours existed anywhere else in the Solar System.

To combat possible bacterial infections, anyone landing on another planet should take a battery of antibiotics, together with their mirror images, and a spaceship crew should include a medically qualified bacteriologist. After returning to Earth, the crew should be isolated for a suitable quarantine period.

Among other ideas put forward by Professor Haldane was a suggestion that there may be planets elsewhere in the Universe where intelligent anaerobic organisms would deliberately kill off all forms of life capable of producing oxygen, which might be as poisonous to them as chlorine is to us. Another suggestion was that Martians, noticing the bright-line spectrum from the neon lights of London, might wonder if we are about to become an O-type star!

Returning to the question of meteors, Professor Haldane thought we may be quite unusually infested with meteorites at the present time, for though meteoric material is found in ocean ooze, no well-authenticated meteorites have ever been found in chalk or other geological formations.

On the question of the past and future of Man, Professor Haldane pointed out that our planet had been habitable by beings like ourselves for 500 million years, yet it had not been colonised from outer space. However, it might have been "seeded" in the remote past. As to the future, we hope that Man, the highest product of evolution, will continue to evolve, but further progress might be limited by the anatomical structure of his brain. There is also a risk that he may suffer a similar fate to that of the Hymenoptera (ants, etc.), who once had a "fall" through parasitism.

In time, Man might bring about the evolution of a mollusc or an insect more morally advanced than himself. In fact inter-specific co-operation may prove to bring greater ethical advancement than intra-specific. Or he may create a species more capable than himself of colonising other worlds.

Finally, Professor Haldane gave it as his opinion that we could probably produce a space-ship with only a part of the money now devoted to war or to football pools.

Discussion

Opening the discussion, the Chairman, Mr. A. C. Clarke, took up the Professor's last point, pointing out that one of the Society's earliest members was Mr. C. Littlewood Askham of the Pools, and that he actually paid for the first issue of our Journal.

The discussion ranged over many subjects, but most attention was given to the possible effect of the absence of a sensation of gravity, and to problems of respiration in strange atmospheres. As to the first, Professor Haldane thought the effects were not going to be as bad as some people thought. People who have experienced long free falls appeared to have been less worried than one would expect. However, they can feel the airflow, which gives them a datum. It may be found that some people would crack up under the strain, but a reasonable number might be capable of adjusting themselves. As to the human body adjusting itself, he remarked that the difference between lying down and running upstairs is much greater than that between *g* and no *g*. He saw no reason why there should be shock from lowered blood pressure, or why the eyesight should be affected, but in reply to a question by Mr. R. A. Smith on possible mental effects, he agreed that the sensations of free fall might cause unpleasant dreams.

Answering questions about respiration, Professor Haldane said that insects could not live on Mars because they need oxygen; no insect could live with even 1/20th of the oxygen in our own air, and the Martian atmosphere is thought to contain less than 1/1,000th as much oxygen as ours. The elimination of nitrogen in an artificial atmosphere would do no harm, as there is no evidence that this gas has any physiological function. Two cases of "deep freeze" with recovery, described in the U.S.A., were mentioned by one questioner who thought the technique might be adopted to reduce oxygen consumption, but Professor Haldane thought we would probably want people to be at their best when voyaging in a space-ship. He did not know if oxygen consumption could be reduced by hypnosis, but he thought it improbable, and in any case undesirable. To a question whether there were organisms which could convert a carbon dioxide atmosphere (as on Venus) into an oxygen atmosphere, he replied that photosynthetic organisms are accustomed to having some oxygen around them to start with, and in any case one could not prepare such organisms without first getting full particulars of the "culture medium" in which they would be required to grow. To a suggestion that oxygen could be obtained from oxides on the surface of Mars, he replied that the process would be very slow.

To Mr. Clarke's question on whether life elsewhere could be based chemically on silicon instead of carbon, Professor Haldane answered that he thought it not impossible, and some complicated silicate structures are known which are interesting, but he "would bet against it." And to a question whether some animal could be planted on a planet and later evolve to intelligence, he answered: "Possibly; but ask me in another century."

A. E. SLATER.

Acknowledgment

The Council wishes to acknowledge with grateful thanks the receipt of a copy of *Analysis of Temperature, Pressure and Density of the Atmosphere extending to extreme altitudes* (Grimminger), kindly donated by Mr. N. H. Strickland.

SOLAR SYSTEM NOTES—1

By Patrick A. Moore, F.R.A.S.

The light skies of summer are often surprisingly favourable for planetary observation, and in spite of this year's long cloudy spells a great many drawings have been made of Venus, now well-placed and glowing like a lamp in the west for some hours after the Sun has set. As Venus is closer to the Sun than we are (67 million miles, compared to our 93 million) we can never see her completely "full"; when she is at her closest, she is invisible to us, as her dark hemisphere is then turned towards the Earth. Because of her dense, cloudy atmosphere, we probably know less about her than about any other body in the Solar System. Venus is indeed a planet of mystery.

An interesting series of observations has been made this year by R. M. Baum, F.R.A.S., a member of this Society, who has charted some curious linear markings intersecting in circular patches. These are not new; Lowell, famous for his theories of Mars, drew them frequently, and they have also been recorded by Douglass and others. Lowell went so far as to refer to them as "canals," but the term is certainly even more unfortunate than in its Martian application, as the Cytherian features are much broader and less well-defined, and certainly different fundamentally. It must be stressed that many other observers (including the present writer!) are quite unable to see the linear markings drawn by Baum, and show only vague, cloudlike shadings exceedingly difficult to define.

Further observations of Venus are urgently needed, as we still do not know the length of her axial rotation or "day." The spectroscope having failed us in this connection, we are forced back upon observations of the positions of the dark shadings, but so far the results are discordant. American observations of this year tend to confirm the supposed period of about 30 terrestrial days, but the question remains very much open, and indeed may not be solved until the first space-ship lands on the planet's surface.

The other Inner Planet, Mercury, was well-placed in the spring of this year, and became quite conspicuous to the unaided eye. An important development here is the recent discovery of an atmosphere, by Dollfus at the Pic du Midi. This atmosphere is, however, very tenuous, and corresponds to what we in the laboratory would call a "vacuum"; it will be of no practical use to the first explorers of the barren Mercurian rocks.

Saturn is also visible in the evening sky, and as the ring-system is now almost edge-on conditions are favourable for observation of the satellites. Nine of these are known, and the largest, Titan, is perhaps of more astronautical interest than Saturn itself, as it is a full 3,500 miles in diameter—larger than Mercury—and has managed to retain its envelope of air, although this atmosphere seems to consist largely of methane and is certainly unbreathable. Owing to its great distance, surface detail on Titan is very hard to see; but recent drawings made in America indicate that the markings are permanent and well-defined. When interplanetary travel has advanced sufficiently, Titan should provide an invaluable base for refuelling and observation, although we can be quite sure that no life, as we know it, will be found there.

AERODYNAMIC HEATING AT HIGH SPEEDS

By T. Nonweiler, B.Sc.

Introduction

The process by which heat is conducted into a body from the boundary layer is quite well understood in relation to aircraft flight; the advent of the guided missile has drawn attention to the effects of flight at supersonic speeds on the mechanism of heat transfer. But, even so, published data has little relevance to the problem of the heating of a missile entering the earth's atmosphere from space, and it is the intention here to deal with one aspect of this last-mentioned problem. The present discussion is restricted in its scope for the sake of convenience as although it is possible to deal quite generally with the problem the analysis is very involved and probably a little out of place here—because the present knowledge of spaceship design hardly justifies the need for an exact and comprehensive examination of all the many factors affecting heat transfer.

We shall attempt to show that we can fill in one of the biggest gaps in existing knowledge, by considering the mechanism of heat transfer at very high speeds—of the order of the escape velocity—and at high altitudes, where the flight Reynolds Number is sufficiently small to justify the assumption of laminar flow in the boundary layer, yet not so small that slipping of the air at the surface is important. In attempting to show this we shall assume that the temperature reached by the body surface is small compared with that reached by the air in the boundary layer. This is a reasonable enough assumption as a temperature of

$$\left(\frac{U}{100}\right)^2 {}^\circ\text{C.} \quad (U \text{ in m.p.h.})$$

is that reached by air in being reduced isentropically to rest relative to a body moving at a velocity U, and since we are here considering flight at speeds of 25,000 m.p.h., it will be evident that unless the surface temperature is small compared with

$$\left(\frac{25{,}000}{100}\right)^2 {}^\circ\text{C.} = 62{,}500^\circ\text{C.}$$

the problem we have posed will have only academic interest!

We shall further restrict the analysis to a study of the flow about a plane surface (acted upon by a uniform air pressure) and we shall neglect the variation of skin temperature with time and—to begin with—with position along the surface—which are reasonable approximations if we are interested in the mean surface temperature of a winged missile gliding down to earth.

Calculation of the Heat Transferred

Using the symbols as defined at the end of this paper we may write down the equation of continuity for steady motion as

$$\frac{\delta(ru)}{\delta x} + \frac{\delta(rv)}{\delta y} = 0 \quad .. \quad .. \quad .. \quad .. \quad (1)$$

and if the pressure on the surface is uniform, the equations of motion for the flow inside a thin boundary layer are

$$r\frac{Du}{Dt} = \frac{\delta}{\delta y}\left(\eta\frac{\delta u}{\delta y}\right) \quad .. \quad .. \quad .. \quad (2)$$

and $$dp = 0 \quad .. \quad .. \quad .. \quad .. \quad .. \quad (3)$$

In addition, we need the energy equation for the thin boundary layer:

$$r\frac{DH}{Dt} = \frac{\delta}{\delta y}\left(\frac{k}{c_p}\frac{\delta H}{\delta y}\right) + \eta\left(\frac{\delta u}{\delta y}\right)^2$$

which, used in conjunction with equation (2), may be written as

$$r\frac{D}{Dt}\left(H + \tfrac{1}{2}u^2\right) = \frac{\delta}{\delta y}\left(\frac{k}{c_p}\frac{\delta H}{\delta y} + \eta u\frac{\delta u}{\delta y}\right) \quad .. \quad .. \quad (4)$$

Finally, from (3) we may write the Perfect-Gas Law as

$$d\left(\frac{rT}{m}\right) = 0 \quad .. \quad .. \quad .. \quad .. \quad (5)$$

The operator

$$r\frac{D}{Dt} = r\left(u\frac{\delta}{\delta x} + v\frac{\delta}{\delta y}\right)$$

and from (1)

$$= \left(\frac{\delta}{\delta x}ru + \frac{\delta}{\delta y}rv\right)$$

Introducing the condition of "no-slip" at the surface,

$$u_o = v_o = 0 \quad .. \quad .. \quad .. \quad .. \quad (6)$$

where suffix "o" is here used to denote conditions at the surface ($y = 0$), and suffix "b" will be used to denote conditions at the outside of the boundary layer [$y = b(x)$]. We may define the outside of the boundary layer to be where

$$\left(\frac{\delta u}{\delta y}\right)_b = \left(\frac{\delta T}{\delta y}\right)_b = 0 \quad .. \quad .. \quad .. \quad (7)$$

That is, the viscous stresses and the heat conduction are zero at the outside edge of the boundary layer. Evidently then from (1) and (6), integrating across the boundary layer

$$\int_o^b \frac{\delta}{\delta x}(ru)\,dy = -(rv)_b \quad .. \quad .. \quad .. \quad (8)$$

and from (2), (6) and (7):

$$\int_o^b \frac{\delta}{\delta x}(ru^2)\,dy = -\left(\eta\frac{\delta u}{\delta y}\right)_o - (ruv)_b;$$

that is, using (8):

$$\int_o^b \frac{\delta}{\delta x}\left\{ru(u-u_b)\right\}dy = -\left(\eta\frac{\delta u}{\delta y}\right)_o \quad .. \quad .. \quad (9)$$

Likewise, integrating (4), from (6), (7) and (8):

$$\int_o^b \frac{\delta}{\delta x}\left\{ru\,(\mathrm{H}-\mathrm{H}_b+\tfrac{1}{2}u^2-\tfrac{1}{2}u_b^2)\right\}dy = -\left(\frac{k}{c_p}\frac{\delta \mathrm{H}}{\delta y}\right) \quad .. \quad (10)$$

We now render the equations non-dimensional by writing:

$$x = s\mathrm{L},\ y = n.b(x),\ u = f(n).u_b,\ \frac{m_b\mathrm{T}}{m.\mathrm{T}_b} = \frac{r_b}{r} = g(n),$$

$$\text{and } \mathrm{H}-\mathrm{H}_b = h(n).(c_p\mathrm{T})_b$$

where we have used the assumption that the surface temperature does not vary with x. Then equations (9) and (10) become, from (5),

$$\eta_o f'(0)/b(x) = b'(x).(ru)_b.\int_0^1 f(1-f)/g.dn \quad .. \quad .. \quad (9^*)$$

$$k_o\, g'(0)/b(x) = b'(x).(ruc_p)_b.\int_0^1 f\left\{-h+\frac{\gamma-1}{2}\,\mathrm{M}^2(1-f^2)\right\}/g.dn \quad .. \quad (10^*)$$

where $\gamma = (c_p/c_v)_b$ and $\mathrm{M}^2 = (u/a)_b^2$

Integrating equations (9*) and (10*) with respect to x, since $b(0) = 0$,

$$\frac{2}{\mathrm{R}}f'(0).(\eta_o/\eta_b).s = \frac{b^2}{\mathrm{L}^2}\int_0^1 \frac{f}{g}(1-f).dn \quad .. \quad .. \quad (11)$$

$$(c_p)_b\left(\frac{\eta_o}{k_o}\right)f'(0)\int_0^1\frac{f}{g}\left[-h+\frac{\gamma-1}{2}\,\mathrm{M}^2(1-f^2)\right]dn = h'(0)\int_0^1\frac{f}{g}(1-f).dn \quad (12)$$

Evidently for zero heat transfer $[h'(0) = 0]$ equation (12) is satisfied by writing

$$-h(n)+\frac{\gamma-1}{2}\,\mathrm{M}^2\,[1-f^2(n)] = 0$$

or since from (6), $f(0) = 0$,

$$h(0) = \frac{\gamma-1}{2}\,\mathrm{M}^2$$

This relation indicates the surface temperature for zero heat transfer to the accuracy possible from the method of approach we have here adopted. The general relation above for $h(n)$ is only an exact solution of the energy equation (4) if the Prandtl Number $(c_p.\eta/k)$ is unity, but Prandtl Number has in fact only a small effect upon the temperature distribution, and the statements above are good approximations to the truth.

However, we are interested in the heat transfer for low skin temperatures—only about, say, 2 or 3 times the ambient air temperature. Consequentially,

if the Mach Number M is large, we may neglect $g(0)$ and $h(0)$ compared with M^2. Also, because of the moderate skin temperature we can conveniently neglect the variation of specific heat and molecular weight between the temperatures T_o and T_b; likewise we can also neglect the variation of (η/k) over the same temperature range, since this is a function of the specific heats.[1] Thus, we may write

$$\left.\begin{aligned} g'(1) = h'(1) \text{ and } g'(0) = h'(0), \text{ etc.} \\ (c_p)_b\left(\frac{\eta_o}{k_o}\right) = (c_p\eta/k)_b = P \\ m_b = m_o \\ \left(\frac{d\eta}{dk}\right)_o = (\eta/k)_o \end{aligned}\right\} \quad .. \quad .. \quad (13)$$

To find the shearing stress and heat transfer at the surface we need to find the values of

$$\left(\eta\frac{\delta u}{\delta y}\right)_o \quad \text{and} \quad \left(k\frac{\delta T}{\delta y}\right)_o$$

as given by equations (9) and (10). We do this by assuming a temperature and velocity distribution in the boundary layer (i.e. assuming the form of $f(n)$ and $g(n)$) and satisfying equations (11) and (12). As is customary in this form of solution, when making this assumption, we approximate to the actual distributions by simulating the boundary conditions at $y = 0$ and $b(x)$ as suggested by the equations (2) and (4); viz.,

$$\left.\begin{aligned} u = \frac{\delta}{\delta y}\left(\eta\frac{\delta u}{\delta y}\right) = \frac{\delta}{\delta y}\left(\frac{k}{c_p}\frac{\delta H}{\delta y} + \eta u\frac{\delta u}{\delta y}\right) = 0, \text{ at } y = 0, \\ \frac{\delta}{\delta y}\left(\eta\frac{\delta u}{\delta y}\right) = \frac{\delta u}{\delta y} = \frac{\delta}{\delta y}\left(\frac{k}{c_p}\frac{\delta H}{\delta y}\right) = \frac{\delta H}{\delta y} = 0, \text{ at } y = b, \end{aligned}\right\} \quad .. \quad (14)$$

These conditions may be written in non-dimensional form as

$$\left.\begin{aligned} f(0) = 0,\ f''(0) = -\left(\frac{g}{\eta}\frac{d\eta}{dg}\right)_o\frac{f'(0).g'(0)}{g(0)}, \\ f(1) = 1,\ f'(1) = 0,\ f''(1) = 0; \\ h''(0) = -\left\{\left[\left(\frac{c_p.g}{k}\right)\frac{d(k/c_p)}{dg}\right]_o\frac{g'(0).h'(0)}{g(0)} + (\gamma-1)PM^2[f'(0)]^2\right\} \\ h(1) = 0,\ h'(1) = 0,\ h''(1) = 0; \text{ and from (13) } \therefore\ g'(1) = 0,\ g''(1) = 0. \end{aligned}\right\} \quad (15)$$

Comparing the relative magnitudes of the functions and constants in (12), it follows that

$$\left.\begin{aligned} g'(0)/f'(0) = h'(0)/f'(0) = O(M^2) \\ h(n) = O(M^2) \text{ and so } g(n) = O(M^2) \end{aligned}\right\} \quad .. \quad .. \quad (16)$$

so that in (15), from (13),

$$\frac{g(0).h''(0)}{g'(0).h'(0)} = \frac{g(0).g''(0)}{[g'(0)]^2} = -\left(\frac{g.d\eta}{\eta\, dg}\right)_o + O(1/M^2)$$

Thus, if we assume the forms of f and g to be given by

$$\left.\begin{aligned} f(n) &= F(n).(1 + a_1 n + a_2 n^2 + a_3 n^3) \\ g(n) &= G(n).(1 + b_1 n + b_2 n^2 + b_3 n^3) \end{aligned}\right\} \quad .. \quad (17)$$

where the coefficients a and b have to be determined from the conditions at $n = 1$ (and so are of unit order), the functions F and G are determined from the known behaviour at $n = 0$. Substituting these expressions in the relations given by (15), and using (13) and (16), we find that

$$F'(n) \to f'(0).(\eta_o/\eta), \text{ as } n \to 0$$
$$\text{and } G'(n) \to g'(0).(\eta_o/\eta), \text{ as } n \to 0$$

where terms of order $1/g'(0)$ have been neglected in comparison with unity, since $g'(0)$ is large if M is large. (This follows from (16) and (17) as $G(n)$ must be of order M^2 and its magnitude we have determined in terms of $g'(0)$ above.)

A particular form for $G(n)$ which satisfies the required boundary conditions is obtained if we put

$$g'(0).n = \int_{g(0)}^{G} (\eta/\eta_o).d\left(\frac{T}{T_b}\right) = \int_{g(0)}^{G} \left[\frac{g(0) + (C/T_b)}{G(n) + (C/T_b)}\right]\left[\frac{G(n)}{g(0)}\right]^{3/2} dG$$

since $dT/T_b \to dG$ as $n \to 0$, and where we have used Sutherland's Formula[2] to account for the variation of viscosity with temperature. Performing the integration, it is possible to simplify the relation for $G(n)$ thus obtained if we recall that over most of the boundary layer $G(n)$ is large, so that except for a small region near $n = 0$ we may write

$$G(n) = g(0).n^{2/3}\left\{\frac{3}{2}\left[\frac{g'(0)}{g(0) + c}\right]\right\}^{2/3}[1 + O(1/M^2)]$$

with $c = C/T_b$; hence by analogy

$$F(n) = f'(0).n^{2/3}\frac{g(0)}{g'(0)}\left\{\frac{3}{2}\left[\frac{g'(0)}{g(0) + c}\right]\right\}^{2/3}[1 + O(1/M^2)]$$

We may accordingly calculate the values of the coefficients in the expressions for $f(n)$ and $g(n)$ in (17) and so find, as $M \to \infty$,

$$\left.\begin{aligned} f(n) &= \frac{1}{9} n^{2/3}(20 - 16n + 5n^2) + \frac{20}{9}\frac{1 - A}{A} n^{2/3}(1 - n)^3 \\ g(n) &= g(0).\left\{\frac{3}{2}\left[\frac{g'(0)}{g(0) + c}\right]\right\}^{2/3} n^{2/3}(1 - n)^3 \end{aligned}\right\} \quad .. \quad (18)$$

whence it follows by comparison with the above expression for $F(n)$

$$\lim_{M \to \infty} [f'(0)] = \frac{20}{9A}\left[\frac{g'(0)}{g(0)}\right]\left\{\frac{2}{3}\left[\frac{g(0) + c}{g'(0)}\right]\right\}^{2/3} \quad .. \quad (19)$$

To determine A we need another condition which we shall take to be

$$g'(0)/f'(0) = \frac{\gamma - 1}{2}\mathrm{M}^2, \text{ when } \mathrm{P} = 1,$$

since for unit Prandtl Number an exact solution of the energy equation (4) is simply

$$h(n) = \frac{\gamma - 1}{2}\mathrm{M}^2.\ f(1 - f) + \mathrm{O}(1)$$

Substituting from (18) and (19) in (12), it follows from (13) that for large values of M,

$$g(0)\left\{\frac{3}{2}\left[\frac{g'(0)}{g(0) + c}\right]\right\}^{2/3} = \frac{\gamma - 1}{2}\,\mathrm{PM}^2\,(\mathrm{I}_1/\mathrm{I}_2) \quad \ldots \quad \ldots \quad (20)$$

where

$$\mathrm{I}_1 = \int_0^1 \frac{f.(1 - f^2)}{n^{2/3}(1 - n)^3}\,dn$$

and

$$\mathrm{I}_2 = \int_0^1 \left[\mathrm{P}\left(\frac{h}{g}\right) + \frac{9}{20}\,\mathrm{A}\,\frac{1 - f}{n^{2/3}(1 - n)^3}\right] dn$$

Evaluating these integrals and solving for A, we find that $\mathrm{A} = 2$ if $\Gamma = \frac{9}{7}$, and

$$g(0)\left\{\frac{3}{2}\left[\frac{g'(0)}{g(0) + c}\right]\right\}^{2/3} = \frac{\gamma - 1}{2}\,\mathrm{PM}^2\left(\frac{2{\cdot}76}{1{\cdot}46 + \frac{9}{11}\,\Gamma\,\mathrm{P}}\right)$$

$$\text{where } \Gamma = \left\{\int_0^1 u\overline{mc_p}\,dn \Big/ \int_0^1 u(\overline{mc_p})_b dn\right\}$$

At the high temperatures existing over the greater part of the boundary layer for large M, the value of the molecular specific heat (mc_p) is believed to be fairly constant,[3] and theory indicates that for air

$$(mc_p)/(mc_p)_b = 9/7.$$

Adopting this then as the value of Γ, and using the values

$$\mathrm{P} = 14/19, \quad \gamma = 7/5, \quad \mathrm{C} = 117^\circ\ \mathrm{K}.$$

for air at normal temperatures, we find that

$$g'(0) = 0{\cdot}052\left\{\frac{g(0) + c}{[g(0)]^{3/2}}\right\}\mathrm{M}^3 \quad \ldots \quad \ldots \quad \ldots \quad (20^*)$$

and from (18), except near $n = 0$,

$$g(n) = 0{\cdot}18[n^{2/3}\,(1 - n)^3]\mathrm{M}^2 \quad \ldots \quad \ldots \quad \ldots \quad (21)$$

From (19) it follows that

$$f'(0) = 0{\cdot}32\left\{\frac{g(0) + c}{\sigma}\right\}\mathrm{M} \quad \ldots \quad \ldots \quad \ldots \quad (22)$$

and from (11), using Sutherland's Formula,

$$\frac{\delta^2}{\mathrm{L}^2} = 0{\cdot}072\,(1 + c)\,\frac{\mathrm{M}^2}{\mathrm{R}}s \quad \ldots \quad \ldots \quad \ldots \quad (23)$$

By definition, the local heat transfer coefficient is:

$$k_h = \left(k\frac{\delta T}{\delta y}\right)_o \Big/ (c_p r u)_b \, (T^* - T_b)$$

$$= \frac{\text{heat conducted into the surface}}{(\tfrac{1}{2} r u^3)_b}$$

where T^* is the "stagnation temperature" as usually defined:

$$T^* = T_b + \left(\frac{u^2}{2c_p}\right)_b = T_b \left(1 + \frac{\gamma - 1}{2} M^2\right)$$

It is worth noting in passing that equation (21) indicates that the maximum temperature reached in the boundary layer is only some 20 per cent. of the stagnation temperature: and in fact dissociation may well cause this proportion to be even smaller—since m is reduced and $g \propto T/m$ is increased by dissociation. However, near the surface dissociation effects are unimportant and from (13) and the definition of $g(n)$

$$k_h = \frac{5}{M^2} \frac{g'(0)}{PR} \frac{L}{b} \frac{\eta_o}{\eta_b}$$

so that from (20*) and (23),

$$k_h = \frac{1{\cdot}3}{s^{\frac{1}{2}}} \left(\frac{1 + c}{RM}\right)^{\frac{1}{2}} \quad .. \quad .. \quad .. \quad (24)$$

It follows that the *mean* heat transfer coefficient is

$$K_h = 2{\cdot}6 \left(\frac{1 + c}{RM}\right)^{\frac{1}{2}} \quad .. \quad .. \quad .. \quad (25)$$

Again, from definition the local skin friction coefficient is

$$c_f = \left(\eta \frac{\delta u}{\delta y}\right)_o \Big/ (\tfrac{1}{2} r u^2)_b$$

so that

$$k_h/c_f = \frac{1}{2P} \frac{5}{M^2} \frac{g'(0)}{f'(0)}$$

that is, from (20*) and (22),

$$k_h/c_f = 0{\cdot}56 \quad .. \quad .. \quad .. \quad .. \quad (26)$$

By analogy with (25) it then follows that

$$C_f = 4{\cdot}7 \left(\frac{1 + c}{RM}\right)^{\frac{1}{2}} \quad .. \quad .. \quad .. \quad (27)$$

It will be noticed that both the heat transfer and the skin friction are less than that predicted by theory applicable to low speeds of flight, by the inclusion of the term $1/\sqrt{M}$.

The value of C_f is comparatively insensitive to the value of P: it varies as

$$\left(\frac{P}{P + 1{\cdot}4}\right)^{1/4}$$

whereas the ratio k_h/c_f varies as

$$1/(P + 1{\cdot}4)$$

Unit of U	Unit of L	Value of Q_F required in				
		kw./sq.m.	cal./cm.²/sec.	H.P./ft.²	lb./ft./sec.	BTU/ft.²/sec.
metres/sec.	metres	$1{\cdot}33 \times 10^{-4}$	$3{\cdot}2 \times 10^{-6}$	$1{\cdot}64 \times 10^{-5}$	$9{\cdot}1 \times 10^{-3}$	$1{\cdot}17 \times 10^{-5}$
km./hr.	,,	$1{\cdot}02 \times 10^{-5}$	$2{\cdot}45 \times 10^{-7}$	$1{\cdot}28 \times 10^{-6}$	$7{\cdot}0 \times 10^{-4}$	$9{\cdot}1 \times 10^{-7}$
ft./sec.	feet	$2{\cdot}25 \times 10^{-5}$	$5{\cdot}4 \times 10^{-7}$	$2{\cdot}61 \times 10^{-6}$	$1{\cdot}52 \times 10^{-3}$	$1{\cdot}95 \times 10^{-6}$
m.p.h.	,,	$4{\cdot}8 \times 10^{-6}$	$1{\cdot}16 \times 10^{-6}$	$6{\cdot}0 \times 10^{-6}$	$3{\cdot}3 \times 10^{-3}$	$4{\cdot}2 \times 10^{-6}$
Stefan's Constant, σ		$5{\cdot}7 \times 10^{-11}$	$1{\cdot}36 \times 10^{-12}$	$7{\cdot}1 \times 10^{-12}$	$3{\cdot}9 \times 10^{-9}$	$5{\cdot}0 \times 10^{-12}$

Heat Transfer to a Flat Plate

If we apply the above results to a flat plate placed symmetrically in the airstream, then the conditions at the outside of the boundary layer are those of the free stream; that is, $u_b = U$, and $r_b = r_a$, $T_b = T_a$, etc. Then from (25) we may calculate that the mean rate of heat transfer to the plate is

$$Q_F = 133 \left(\frac{p_a}{p_{SL}} \right)^{\frac{1}{2}} \frac{U^3}{\sqrt{L}} \text{ kw./sq.m.} \quad .. \quad .. \quad (28)$$

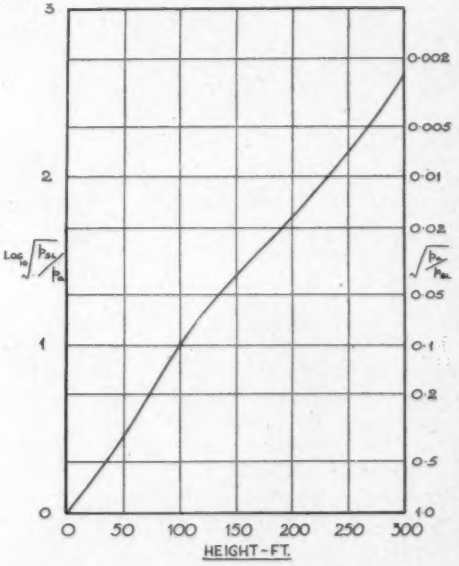

FIG. 1. Variation of heat transfer with height, with height in thousands of feet.

where U is in km./sec., and L is in metres. Here we have abandoned the non-dimensional notation, and consequentially the value of the numerical constant in (28) depends of course on the units employed. The Table above lists some of the values of the constant which may be found useful in practical applications. Fig. 1 shows the variation of heat transfer with height—that is, the values of $\sqrt{p_a}$—according to the N.A.C.A. Standard Atmosphere.

The conduction of heat into the surface from the boundary layer is of course off-set to a greater or less extent by the radiation of heat away from the surface of amount

$$\epsilon_s . \sigma . T_0^4$$

where ϵ_s is the emissivity of the surface, σ is Stefan's Constant—its value in various units is shown in the Table above—and T_o is the surface temperature in degrees Kelvin. The radiation to the surface from the air can in most applications be neglected.

Effect of Varying Surface Temperature

Although we have so far considered the surface temperature to be invariant with x, it is important to notice that the previously derived results are valid if the temperature does in fact vary along the surface—provided only that it is everywhere small compared with the stagnation temperature.

For, from (18) and (21), it follows that the velocity and temperature distributions are independent of the surface temperature, except in a small region near the surface, for the high values of M considered; thus the analysis remains fundamentally unaltered if we consider $g(0)$, $h(0)$, $f'(0)$, $g'(0)$, etc., as functions of x. Equations (11) and (12) then become—using (13)—

$$\frac{2}{R}\int_0^s f'(0)\,\frac{\eta_o}{\eta_b}\,ds = \frac{b^2}{L^2}\int_0^1 \frac{f}{g}(1-f)\,dn \qquad \ldots \qquad (11^*)$$

$$P\int_0^s f'(0)\,\frac{\eta_o}{\eta_b}ds.\int_0^1 \frac{f}{g}\left[-h + \frac{\gamma-1}{2}M^2(1-f^2)\right]dn$$

$$= \int_0^s g'(0)\,\frac{\eta_o}{\eta_b}ds.\int_0^1 \frac{f}{g}(1-f)\,dn. \qquad \ldots \qquad (12^*)$$

The consequent results follow as before, since $f'(0)$ and $g'(0)$ both vary with s directly as (η_b/η_o), i.e. as

$$\frac{g(0)+c}{[g(0)]^{3/2}}$$

and therefore from (11*), b^2/L^2 varies linearly with s; and in particular, it follows that the rate of heat transfer and skin friction vary with $1/s^{\frac{1}{2}}$, as given by (24) and (26).

The Transition to Turbulence

As the results above apply to a laminar boundary layer, it is pertinent to enquire under what conditions laminar flow might exist. At the high Mach Number of flight we are considering there are no data on the conditions leading to turbulent flow, although tunnel tests tend to show that an increase in Mach Number leads to a delay in the transition to turbulence.

A simple dimensional concept which is of relevence if the transition is caused by atmospheric turbulence—and not by an adverse pressure gradient on the surface—relates transition to the existence of a pressure gradient which is large compared with the rate of change of the shearing stress in the boundary layer.[4] Stated formally

$$\Delta(R_T) \propto \frac{d\bar{p}}{dx} \Big/ \frac{1}{b(x)}\left(\eta\,\frac{\delta u}{\delta y}\right)_o$$

where R_T is the Reynolds Number of Transition and $\bar{p}$ is the root-mean-square of the pressure fluctuations caused by atmospheric turbulence; in non-dimensional terms

$$\Delta'(R_T) \propto \frac{1}{\bar{R}^{\frac{1}{2}}} \left(\frac{\bar{u}}{a}\right)^5 \left\{\frac{\eta_b . R . b^2(L)}{\eta_o . f'(0) . L^2}\right\} \frac{1}{M^3}$$

where $\bar{R}$ is the Reynolds Number of Turbulence and $\bar{u}$ is the root-mean-square of the velocity fluctuations. Evidently, from (11),

$$\Delta'(R_T) \propto \frac{1}{\bar{R}^{\frac{1}{2}}} \left(\frac{\bar{u}}{a}\right)^3 \frac{1}{M^3} \Big/ \left\{\int_0^1 f(1-f)/g.dn\right\}$$

It appears then that transition is dependent not only on the velocity fluctuations in the free-stream, but also on the scale of the turbulence. An examination of results at low flight speeds suggest in fact that in the atmosphere

$$R_T = \frac{1}{3}\left\{M^3 \int_0^1 f(1-f)/g.dn\right\}^{\frac{1}{2}} . 10^8 \quad .. \quad .. \quad (29)$$

whence it follows, from (22) and (23), that in the application considered here, the boundary layer is laminar if

$$L < \frac{10}{\sqrt{M}} \left(\frac{p_{SL}}{p_a}\right) \text{ ft. approximately} \quad .. \quad .. \quad (30)$$

For most practical purposes we may take it that the boundary layer should be completely laminar at heights above about 10 miles, if atmospheric turbulence causes transition to occur.

This may be a pessimistic interpretation of the result, for atmospheric turbulence may be almost non-existant at these altitudes—at least compared with its intensity at low altitudes upon which our estimate is based. However, a warning must be given that, although the above suggestions are quite simple, the subject we are considering is very complex and observations do not fit in with any well-defined pattern even at low-speeds, so that an extrapolation to high flight-speeds such as we have attempted should be treated as suspect.

There are of course other factors influencing transition: in particular increasing pressure along the surface quickly produces transition to turbulence, but by correct design it should not be difficult to avoid this in supersonic flight. Surface roughness is another aggravation and a limit can be set to the permissable height of roughnesses in order that they may not materially affect the flow. At the tip of a small projection of height ϵ

$$u_\epsilon = \left(\frac{\delta u}{\delta y}\right)_o \epsilon = u_b . f'(0) . \left(\frac{\epsilon}{b}\right)$$

$$\text{i.e.} \quad R_\epsilon = \frac{r_o u_\epsilon \epsilon}{\eta_o} = \tfrac{1}{2} c_f R^2 \left(\frac{r_o \eta^2_b}{r_b \eta^2_o}\right)\left(\frac{\epsilon}{L}\right)^2$$

It is found that if $R_\epsilon < 50$ the flow closes up behind a projection instead of forming a vortex wake, so that—taking the mean value of c_f from (27)—to avoid the formation of eddies

$$\frac{\epsilon}{L} < 7\,\frac{T_o}{T_b}\left(\frac{M}{R^3}\right)^{\frac{1}{2}}\left(\frac{x}{L}\right)^{\frac{1}{2}} \quad .. \quad .. \quad .. \quad (31)$$

It will be seen that an increase of Mach Number has a small effect but allows an increase in tolerable roughness. Generally R is largest at the lower altitudes and substituting $R < R_T$, from (29) the permissible roughness limit is

$$\frac{\epsilon}{L} < 10^{-5}\,\frac{T_o}{T_b}\left(\frac{x}{L}\right)^{\frac{1}{2}}/M^{\frac{1}{2}}$$

from which it appears that a few thousandths of an inch should be a realistic tolerance for roughness in most practical cases, except near the leading edge.

Surface Slip

It is known that the condition of "no-slip" at the surface is valid if the air is acting as a homogeneous medium. It is usual to interpret this as meaning that the molecular mean free path must be small compared with the boundary layer thickness.

Now from (21) the mean air inverse-density in the boundary layer is given by

$$\int_0^1 g(n).dn = 0{\cdot}014\ M^2$$

which we may take as characteristic for the purpose of estimating the mean free path λ. Thus, taking a mean value of the boundary layer thickness from (23),

$$\frac{\lambda}{b} = 10^{-8}\,\frac{r_{SL}}{r_b}\,\frac{\sqrt{MR}}{L} \quad (L \text{ in feet}) \quad .. \quad .. \quad (32)$$

If we assume—albeit arbitrarily—that a value of this ratio less than 1/100 indicates that we may treat the boundary layer flow as homogeneous, then the condition of no-slip is appropriate if

$$L\left(\frac{p_a}{p_{SL}}\right) > \frac{M^2}{10^5} \quad (L \text{ in feet}) \quad .. \quad .. \quad .. \quad (33)$$

This sets an upper limit to the altitude at which the theory we have described is valid.* In relation to entries from space we might expect the value of M^2 to be of the order of 10^3 and L of the order of 100 ft., so that the effects of surface slip may be neglected at heights where the pressure is more than 10^{-4} atmospheres; that is, at heights below about 40 miles.

Effect of Surface Angle

We have based our analysis on the assumption that the Mach Number of flight is high, but in fact we have assumed that the Mach Number of the flow *outside the boundary layer* is large. This is rather more restrictive.

* It is interesting to note that this is precisely the same limitation which would be imposed by considering (b/L) small in comparison with unity—as we may easily verify from equation (23). The boundary layer must be thin compared with the body dimensions if the fundamental boundary layer momentum and energy equations as used here are to be valid.

At high flight Mach Number the temperature behind a shock wave producing a finite deflection is large—of the order of the stagnation temperature—and it follows that the local speed of sound is then of the same order as the flight speed; in other words the Mach Number behind the shock wave is of unit order, and not large. If the Mach Number *behind* the shock wave (as well as that in front) is to be large the stream deflection must be small: viz. $\alpha = O(1/M_a)$ where α is the angle of the surface to the direction of motion.

There is not the same restriction in accelerated flow, since an expansion produces an increase in local Mach Number, though at high flight Mach Number it is possible to expand the flow through only a small angle α—of order $1/M_a$—before the air pressure is (theoretically) reduced to a vacuum.

Thus the analysis is generally applicable to surfaces inclined at a small angle to the free-stream:

$$\text{i.e.} \quad |\alpha| = O(1/M_a) \qquad .. \quad .. \quad .. \quad (33)$$

This may be proved quite simply on the lines suggested above, and it follows that

$$\frac{u_b}{u_a} = 1 + O(1/M_a^2) \qquad .. \quad .. \quad .. \quad (34)$$

$$\text{and } \frac{\rho_b}{\rho_a}, \frac{T_b}{T_a}, \frac{p_b}{p_a} = O(1) \qquad .. \quad .. \quad .. \quad (35)$$

We may deduce as in equation (28), using the above relations, that the mean rate of heat transfer to an inclined plate is

$$Q = \left(\frac{p_b}{p_a}\right)^{\frac{1}{2}} Q_F \qquad .. \quad .. \quad .. \quad (36)$$

The ratio $(p_b/p_a)^{\frac{1}{2}}$ is a function of (αM_a) and is shown in Figs. 2 and 3, for both compression and expansion. Included also in the figures is a graph showing the ratio of the local Mach Number M to the free-stream Mach Number M_a. The effect of even these small surface angles on the rate of heat transfer will be seen to be very large.

Applications

To illustrate the use of the preceding results, the mean surface temperature of a missile in the equilibrium condition—where the heat lost by radiation exactly equals that transferred from the boundary layer—has been calculated for

(*a*) a circling orbit, and
(*b*) level flight at a speed equal to the escape velocity.

The results are shown in Figs. 4 and 5. In the first-mentioned application the skin temperature is calculated for various values of the surface angle to the direction of motion; and in the second, the temperature on the upper surface of the wing is estimated for different wing loadings. Both examples illustrate again the need for small surface angles—that is, thin wings and low wing loadings—if high temperatures are to be avoided.

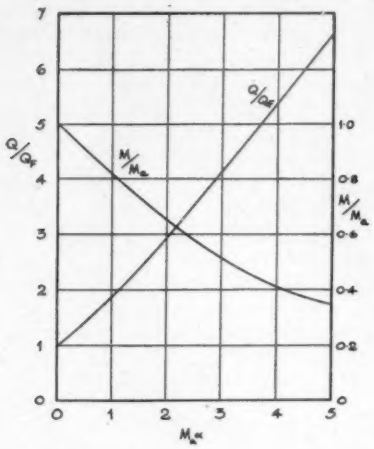

FIG. 2.

Increase in rate of heat transfer and decrease in Mach Number behind shock wave producing deflection α (radians).

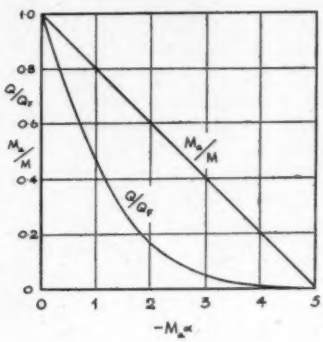

FIG 3.

Decrease in rate of heat transfer and increase in Mach Number behind expansion wave producing deflection α (radians).

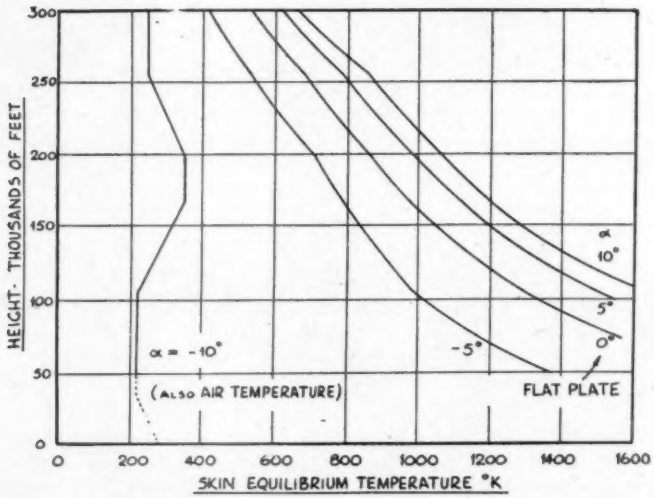

FIG. 4. Surface temperature of missile in circular orbit in terms of α (inclination of surface to direction of motion).

Although the equilibrium temperature is approached assymptotically and might seem to be only of academic interest, in practice after only a few minutes the surface temperature will be indistinguishable from its equilibrium value. A more important effect on the applicability of the results, however, is caused by the increase in the heat transfer near the leading-edge of the surface, which leads to higher surface temperatures than the mean in this region. On the basis of our results the rate of heat transfer varies as $(L/x)^{\frac{1}{2}}$, from which it would follow that the equilibrium temperature varies as $(L/x)^{\frac{1}{4}}$; thus it is only over a relatively small region of the surface that the ultimate temperature is significantly higher than the mean. The increase locally in heat transfer is more important in its effect upon the *rate* at which the equilibrium state is reached.

Again, it should be noted that these are *surface* temperatures and that the bulk of the skin may be at a much lower temperature, due to the conduction of heat through the skin into the interior of the missile. These and other related problems are beyond the scope of the present argument, but it should be noted that the concept of "mean equilibrium temperature" is not the complete answer to the heat transfer problem.

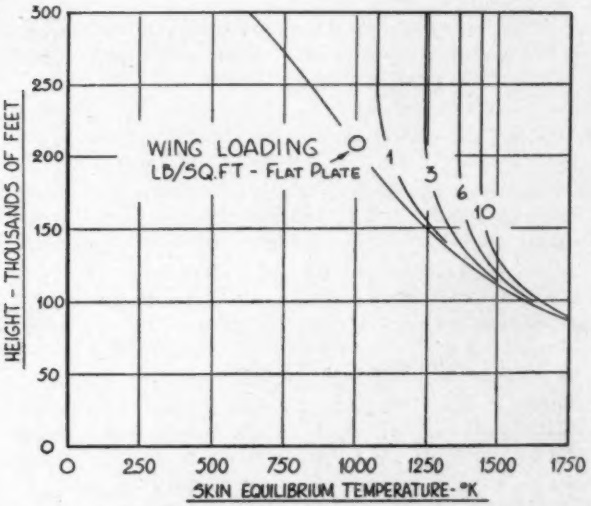

FIG. 5. Wing surface temperature of missile circling Earth at escape velocity.

It should also be noted that some of the author's previous work on this problem[5] was based on an extrapolation of existing heat transfer data which by comparison with the present results appear to yield too optimistic an answer. However, it seems that the difference is not big enough to invalidate the conclusions reached in that work, although it serves to emphasize the point then

made that fundamental analysis of the problem of heat transfer at high Mach Number is greatly needed, and much more needs yet to be done.

Conclusions

1. We have considered the problem of finding the temperature of a plane surface on a missile moving steadily at high speed through the atmosphere, at heights where the boundary layer flow is laminar and does not slip at the surface.

2. By integrating the momentum and energy equations across the boundary layer, and approximating to the temperature and velocity distributions therein, it is shown that the mean rate of heat transfer is given for dry air by

$$K_h = 2{\cdot}6\left(\frac{1+c}{RM}\right)^{\frac{1}{2}}$$

3. The mean skin friction coefficient is found to be given by

$$C_f = 1{\cdot}8\ K_h$$

4. The temperature distribution in the boundary layer is predicted from the boundary conditions at the surface and the outside edge of the layer. It is shown that the temperature reaches a maximum of less than a fifth of the stagnation temperature at a distance of about a fifth of the boundary layer thickness out from the surface.

5. The rate of heat transfer varies locally as $\sqrt{L/x}$ and the above results are shown to be valid even if the surface temperature varies, provided only that it is small compared with the stagnation temperature.

6. It is suggested that the Reynolds Number of transition to turbulence is large at very high speeds of flight and it is therefore to be expected that the boundary layer will be laminar at all heights above about 10 miles.

7. The assumption of zero-slip at the surface made becomes inapplicable if the molecular free path becomes of the order of the boundary layer thickness. As a practical limit we may assume that surface slip is unimportant if the pressure over the surface is more than 10^{-4} atmospheres.

8. The angle of the surface has an important effect upon the rate of heat transfer because it affects the state of the air outside the boundary layer. It is shown that the above results apply only to slender bodies, and that the rate of heat transfer varies as the square root of the surface pressure (assumed constant).

9. It should be emphasized that the approach is only approximate, designed to give the order but not the exact value of the various parameters.

List of Symbols

C Sutherland's Constant, $\eta \propto T^{3/2}/(T + C)$.

C_f Mean skin friction coefficient, $= \int_0^1 c_f\, ds$.

H	Total heat.
K_h	Mean heat transfer coefficient, $= \int_0^1 k_h ds$.
L	Length of plate.
M	Mach Number of air outside the boundary layer, $= (u/a)_b$.
M_a	Mach Number of flight, $= (U/a_a)$.
P	Prandtl Number, $= (c_p\eta/k)_a$.
R	Reynolds Number of surface, $= (ruL/\eta)_b$.
$\bar{R}$	Reynolds Number of turbulence, $= (r\bar{u}l/\eta)_a$ where l is characteristic length.
R_T	Reynolds Number at which transition appears on surface.
Q	Mean rate of heat transfer.
Q_F	Mean rate of heat transfer to flat plate, $(\alpha = 0)$.
T	Temperature.
U	Flight speed.
a	Velocity of sound, $= \sqrt{\gamma p/r}$.
b	Thickness of boundary layer.
c	$= C/T_b$.
c_f	Local skin friction coefficient, $=$ friction$/\frac{1}{2}r_b u_b^2$.
c_p	Specific heat at constant pressure, $= \delta H/\delta T$.
$\bar{c}_p$	Mean specific heat from $T_b°$ to $T°$, $= (H - H_b)/(T - T_b)$.
c_v	Specific heat at constant volume.
f	$= u/u_b$.
g	$= r_b/r$.
h	$= (H - H_b)/(c_p T)_b$.
k	Thermal conductivity.
k_h	Local heat transfer coefficient, $=$ rate of heat transfer$/(\frac{1}{2} r_b u_b^3)$.
m	Molecular weight.
n	$= y/b$.
p	Pressure.
$\bar{p}$	Root-mean-square of pressure fluctuations in atmosphere.
r	Density.
s	$= x/L$.
t	Time.
u	Component of velocity along x-axis.
$\bar{u}$	Root-mean-square of velocity fluctuations in atmosphere.
v	Component of velocity along y-axis.
x, y	Orthogonal coordinates, origin at leading edge of plate, x-axis taken along plate surface.
Γ	$= \int_0^1 um\bar{c}_p\, dn / \int_0^1 u(m\bar{c}_p)_b\, dn$.
$\Delta(R_T)$	Function of Reynolds Number of Transition—see page 168.
α	Angle between surface and free stream (positive for forward facing surfaces).
γ	$= (c_p/c_v)_a$.
ϵ	Height of small projection of surface roughness.

ϵ_s Surface emissivity.
η Viscosity.
λ Molecular mean free path.
σ Stefan's Constant.
Suffix: *SL* refers to conditions in still dry air at sea-level.
a refers to conditions in the free stream.
b refers to conditions at the outside of the boundary-layer.
o refers to conditions at the plate surface.
ϵ refers to conditions at $y = \epsilon$.

The symbol $O(M^n)$ is used to denote a quantity X, say, such that X/M^n is finite as $M \to \infty$.

Primes are used to denote differentiations, e.g. $f'(n) = \frac{df}{dn}$.

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METEORS AND SPACE TRAVEL*

BY MICHAEL W. OVENDEN, M.A., B.Sc., F.R.A.S.

In a short supplement to A. C. Clarke's article [*J.B.I.S.*, **8**, 157 (July, 1949)] G. von Pirquet extends the calculations there given to the problem of interstellar travel, and concludes that the existence of cosmic dust renders the interstellar rocket completely impracticable, even if other and more important considerations did not prevent its realization [*ibid.*, **9**, 153 (July, 1950)]. In a recent letter [*ibid.*, **10**, 45 (January, 1951)] H. E. Ross has queried the assumption of von Pirquet that the density of meteoric material in interstellar space is the same as that in the solar system. The present paper attempts a brief analysis of the position from present astronomical data.

Meteor Observations

If an appreciable proportion of observed meteors were of interstellar origin then an appreciable proportion of observed meteor velocities when corrected for the orbital motion of the Earth would be above the parabolic velocity. The velocity of a meteor is the parameter of its motion which is the least easily determined from visual observations since only a skilled observer can estimate the duration of a transient and unexpected phenomenon such as a meteor of total duration only $\sim$ 1 sec. with an accuracy of 20 per cent. Further duplicate observations are necessary to obtain a true value of velocity. To use visual meteor velocities assumptions must be made prior to any statistical analysis.

* *A note on the recent paper by Ing. G. von Pirquet.*

The earlier work of Hoffmeister and Öpik [*Tartu Obs. Publ.*, **30**, No. 5 (1940); M.N.R.A.S., **100**, 318 (1940), etc.], led to the conclusion that an appreciable proportion (about 60 per cent.) of the fainter visual sporadic meteors had hyperbolic velocities. The assumptions of this work and the methods of analysis have been criticized by Porter [M.N.R.A.S., **103**, 134 (1943), *et. al.*] who, from a careful statistical analysis of a number of meteor observations by experienced visual observers, found no evidence for any interstellar component to the visual meteors.

More accurate velocities may be obtained by interrupted-exposure photography, but these techniques are applicable only to the brighter meteors, and duplicate observations are rare. With the development of methods of obtaining meteor velocities by radar techniques [Ellyett and Davies, *Nature*, **161**, 596 (1948)] sufficient accurate velocities are available for statistical analysis. Radar experiments specially designed to examine this question of hyperbolic meteors have been performed recently [Almond, Davies and Lovell, *The Observatory*, **70**, 112 (June, 1950)]. They found no evidence of any hyperbolic meteors, and conclude that if any such interstellar meteors exist, they cannot account for more than 1 per cent. of the visual sporadic meteors; the meteors of a normal shower cannot be hyperbolic. This conclusion has been confirmed independently by a different radar method by Millman and McKinley (*ibid.*).

Observations of Interstellar Dust

From these radar meteor observations, it is not possible to do more than set an upper limit to the number of interstellar meteors which, for this investigation, can only be considered crude. To obtain a further indication of the number of particles in interstellar space, consideration is made of observations of interstellar matter.

Interstellar matter occurs both as gas and dust, the distribution of both forms being closely related, although the contribution made by the gas to the mean density is much greater than that of the dust. Gaseous interstellar matter is detected by the presence of "interstellar lines" in the spectra of early-type stars, while dust particles are recognized by the selective absorption of starlight (the well-known "space-reddening" effect).

A simple analysis of the space-reddening effect yields a reasonably unambiguous value for the mean density of the dust component of interstellar material, and also of the mean particle size, on the assumption that the interstellar dust is of similar composition to meteoritic matter. Table I gives the general results for two typical interstellar clouds, and for general interstellar space. This table is taken from Waldmeier [*Einführing in die Astrophysik*, Verlag Birkhaüser Basel (1948)].

The mean particle size is far below the size significant for the present discussion. When the distribution in particle size about the mean is sought, it is not possible to derive unambiguous conclusions. A detailed discussion of this problem has been given by C. Schalen [*Beiträge zur Theorie der Interstellaren Absorption*, Uppsala Astr. Obs. Annaler, Bd. I, No. 2 (1939)]. By comparing

TABLE I

Object	Absorption	N cm.$^{-3}$	Density g/cm.^{3}	Total mass	r_0
Auriga-Taurus cloud	1·90^m	$1{\cdot}7\times10^{-11}$	$0{\cdot}4\times10^{-25}$	$35\times$sun	$\sim10^{-5}$cm.
Cepheus cloud ..	1·30^m	$2{\cdot}8\times10^{-11}$	$0{\cdot}6\times10^{-25}$	$340\times$sun	,,
Interstellar space ..	0·50^m/kpc.	$0{\cdot}7\times10^{-11}$	$0{\cdot}4\times10^{-26}$	$0{\cdot}5\times10^{-4}$sun/pc^3	,,

the selective absorption curve for interstellar matter with the optical properties of particles of nickel, iron, copper and zinc (materials in iron meteorites), he finds best fit for a distribution of the Gaussian type. The normalized distribution given by Schalen is:

$$\phi(r) = \frac{1}{\sigma\sqrt{2\pi}}\ exp\left[-\ \frac{1}{2\sigma^2}\ (r - r_0)^2\right] \quad .. \quad .. \quad (1)$$

where the mean diameter $r_0 = 10^{-5}$ cm., and the dispersion $\sigma = 3 \times 10^{-6}$ cm. There is some uncertainty in the value of σ. If σ is much less than the chosen value, however, the distribution approaches that of:

$$r = r_0 \quad .. \quad .. \quad .. \quad .. \quad .. \quad (2)$$

which Schalen has shown to be inconsistent with observation. The value of σ was chosen because of uncertainty in the optical properties of the materials for $r \gg 10^{-5}$ cm., but if σ is too large, the distribution approaches

$$\phi(r) = \text{const.} \quad .. \quad .. \quad .. \quad (3)$$

which, for the range of particle size important in producing the selective absorption, gives a curve of opposite slope to the observed curve. Thus, while the value of σ is only an approximation, it should give a realistic picture of distribution of particle-size in the interstellar dust. Distribution (1) will be used in the following discussion.

The fraction of particles whose diameter lies within the range r to $(r + dr)$ $= \phi(r)$ as given by (1). The number lying between r and $(r + dr)$ is therefore given by

$$N\phi(r) = \frac{N}{\sigma\sqrt{2\pi}}\ exp\left\{-\ \frac{1}{2\sigma^2}\ (r - r_0)^2\right\} \quad .. \quad .. \quad (4)$$

where N is the total number of particles, and is given in Table I for various circumstances. The total number of particles with $r > r_1$ is given by $n(r_1)$ where

$$n(r_1) = \int_{r_1}^{\infty} \frac{N}{\sigma\sqrt{2\pi}}\ exp\left\{-\ \frac{1}{2\sigma^2}\ (r - r_0)^2\right\} dr \quad .. \quad (5)$$

Putting $t = \dfrac{(r - r_0)}{\sigma}$, $dt = dr/\sigma$,

$$n(r_1) = \frac{N}{\sqrt{2\pi}} \int_{\frac{(r_1 - r_0)}{\sigma}}^{\infty} exp(-t^2/2)dt.$$

$$= \frac{N}{2} P\left(\frac{(r_1 - r_0)}{\sigma}\right) \quad .. \quad .. \quad .. \quad (6)$$

where $P(x) = \sqrt{\frac{2}{\pi}} \int_{-x}^{\infty} exp\,(-t^2/2)\,dt$. $P(x)$ is a well-known function in the theory of probability, and tables with argument x are available.

The critical size taken by von Pirquet is $r_1 = 10^{-3}$ cms., whence $x \doteqdot 300$. The maximum value of x for which tables of $P(x)$ are available is 10 (Mathematical Tables Project of the W.P.A. for the City of New York, 1942).

$$P(10) = 1{\cdot}5 \times 10^{-23}, \text{ or } n(r_1) \doteqdot 5 \times 10^{-35}.$$

This corresponds to $r_1 = 4 \times 10^{-5}$ cms.

Using von Pirquet's data of velocity and size, namely:

area of space-ship $= 10^6$ sq. cm.
velocity $= 10^{10}$ cms./sec.

the volume swept out per second $= 10^{16}$ cms.^{3} A collision with a particle above the critical size of 4×10^{-5} cms. would occur on the average *once every* 10^{19} *secs., or, approximately,* 10^{11} *years.*

Within an interstellar cloud, the frequency of collision would be between 10 and 100 times as great.

While σ may be in error, it should be remembered that the critical value of r_1 for a collision is ~ 100 times the value here taken.

Conclusion

The great concentration of meteoric matter in the solar system is not surprising, since the internal structure of meteorites shows that these bodies, and presumably meteors also, must have been formed under conditions of high temperature and pressure within a body of planetary dimensions, and it is reasonable to suppose that they are the remnants of an exploded planet.

Recently, the suggestion has been made that the interstellar dust may be composed of dielectric particles, instead of metallic ones [Oort and van der Hulst, *Obs. Utrech XI*, pt. 1 (1946), *et al.*]. Values of $r_0 = 6{\cdot}2 \times 10^{-5}$ cm. and $N = 1{\cdot}3 \times 10^{-13}$ are obtained, but the density of the particles is only ~ 1. Calculations on similar lines to the above do not give significantly different results.

It would still be possible, without being contradicted by observation, to hold that up to 1 per cent. of sporadic meteors are interstellar, but that they

form a different group of particles as regards size distribution from the interstellar dust observed optically. There is, however, no reason to believe that this is the case.

The conclusion, as far as present observations can tell us, therefore, is that the danger to an interstellar rocket of collision with interstellar dust particles is negligible.

NOTES AND NEWS

Second International Congress on Astronautics

Members will have received, with the May issue of the *Journal*, the detailed programme of the Second International Congress, the final arrangements for which have now been made. It is hoped that as many as possible will attend the public meetings on the 6th, 7th and 8th, as well as the concluding dinner at St. Ermin's Hotel (adjacent to Caxton Hall) at which the delegates will be guests of the Society. Tickets are now available from the Secretary (price £1 11s. 6d. each) and early application is advised.

The Secretary would be very pleased to hear from any members who would be willing to offer accommodation to delegates, with a note of their terms. It is becoming increasingly difficult to obtain hotel reservations in London at a reasonable price, and many of the delegates come from countries where the currency allowed for travel is very limited. Assistance in this respect would therefore be extremely welcome.

Assistance is also sought from members who would be willing to act as translators of material received before the Congress or as interpreters (in French or German) at the working sessions and possibly at the public meetings.

Increased Subscription Rates.

An Extraordinary General Meeting of the Society was held at Caxton Hall on May 26, 1951, in connection with the Council's proposals for increased membership subscriptions, a full explanation of which, together with ballot papers, had previously been circulated to all members with the March *Journal*. These, briefly, recommended that the annual subscriptions payable by existing members be increased as from January 1, 1952, to the following scale:—

Fellows £2 12s. 6d.; Members £1 11s. 6d. (under 21 £1 1s. 0d.) and that the Entrance Fee be increased to 10s. 6d.

The Chairman, Mr. A. C. Clarke, opened the meeting with a few remarks to amplify the circular letter. He explained that the growing normal day-to-day administration of the Society had been placing a severe strain upon its voluntary officers, and it had been obvious for some time past that full-time assistance was necessary. Our initial plans in this direction were of a very modest character, and we envisaged merely finding some accommodation, probably in the suburbs, and engaging a full-time secretarial assistant to handle the routine work. Even these modest plans, however, necessitated finding some additional income of the order of £500 per annum.

The Chairman then said that the results of the voting from members had been most encouraging, but several letters had been received from members arising from the proposed increases which might be discussed. One member had asked if we could not obtain additional revenue from increased advertising in the *Journal*. The answer here was that the member simply had not appreciated the difficulty of obtaining advertisements for such a small and specialised journal as our own. The advertisements which did appear, have, in most cases, been the result of a considerable amount of work, out of all proportion to the revenue received, and which in any case was quite insignificant in relation to our needs.

Another suggestion was that we imposed admission charges to lectures and film shows. This could not be adopted for two reasons; firstly, it was against the Council's policy to charge for admission to lectures, especially as many of our visitors subsequently become members, and it is patently undesirable to deter interested persons from coming along to meetings; and secondly, in the case of film shows, it is normally a condition that films are made available to us on the strict understanding that no admission charges be made.

A proposal from Mr. B. M. Adkins was then read to the effect that the increased rates should not apply to students under the age of 25 years.

In opening the subsequent discussion, Mr. Hope-Jones stated that he opposed Mr. Adkins' proposal. The important thing was that the Council's proposals did not represent a snap decision, nor were they taken without giving other possibilities a very fair hearing. The proposals advanced by the Council had been the result of careful thought, and they deserved full and unqualified support.

Another member pointed out that all sorts of proposals similar to that suggested by Mr. Adkins could be advanced for other classes of members, but it was obvious that no exemptions of this sort could be made since the present total of £500 left an exceedingly small margin in any case.

The Chairman then asked that the meeting express its feelings, and it was unanimously decided that the Council's proposals be adopted and given full support.

The results of the postal ballot were announced by the Chairman and are as follows:—

	For	*Against*	*Total*
Members	493	16	509
Fellows	118	9	127
	611	25	636

Following the conclusion of the main business, the meeting was then thrown open to general discussion. A number of varied and interesting topics were advanced for discussion, including the suggestion raised by Dr. Martyn that the B.I.S. should change its name by deleting the word "British" in its title. A note about this will appear in a later issue of the *Journal*, when the various letters received will also be discussed.

At the conclusion of the meeting, Mr. Hope-Jones rose again to say that he wished to propose a vote of thanks to the officers of the Society for their labours in the past. He felt that the present meeting had marked an important milestone in the history of the Society, and this present was a fitting time for such an acknowledgment to be made.

Mr. A. E. Dixon seconded this proposal, which was carried with acclamation.

The Chairman replied that he wished to thank the meeting for its action, and was grateful to Mr. Hope Jones for his exceedingly kind words.

Astronautical Exhibition at the Palais de la Découverte

Members visiting Paris are strongly advised not to miss the magnificent astronomical exhibits at the Palais de la Découverte, Avenue Franklin D. Roosevelt, Paris VIII^{e}. A large collection of models and illuminated transparencies gives a vivid picture of the planets, stars and nebulae, and of particular interest to our readers will be the room devoted to astronautics. This contains many murals explaining the principles of rocket propulsion, interplanetary navigation and communication, the danger of meteorites—and even relativity corrections on interstellar voyages! The main exhibits are a V.2 motor and a full-sized mock-up of a spaceship cabin, showing the pilot at the controls and one of the crew members climbing through a man-hole in the floor.

Film Programmes

A series of very successful film-shows was given by the Society in Birmingham, London and Manchester on March 17, 24 and 31 respectively. Despite repeat performances, it was impossible to issue tickets to all those who applied for them.

Among the films screened (not all at each performance) were the following:

Rocket Instrumentation. A 15-minute sound film showing the work of the optical and radio tracking equipment (including DOVAP) in use at White Sands. It contained, amongst other extremely interesting material, the only shots we have seen of a V.2 returning to earth.

The High Altitude Research Programme and *The Missile Programme of the Johns Hopkins University Applied Physics Laboratory.* These two 10-minute colour films (silent) were mostly concerned with V.2 and Aerobee firings at White Sands and on the U.S.N. "Norton Sound." They showed the preparation of the missiles for launching and contained some impressive rocket-borne camera sequences.

The Story of Palomar. A first-class 40-minute sound film, in colour, showing all the stages in the building of the 200 inch reflector, and also containing a good deal of interesting astronomical material and photographs of the scientists involved in the project.

We would like to record our thanks to the Army Kinema Corporation, the U.S. Office of Naval Research and the U.S. Embassy for the loan of these films.

Interplanetary Advertising

A rather effective advertisement has recently appeared on the London hoardings on behalf of Charrington's, the well-known brewers, depicting a rocket headed moonwards, astride which is the rocketeer holding, need you guess . . . ?

More tasteful but not so tasty is the advertisement by the Sperry Gyroscope Company which appears in the Festival South Bank guide. This includes a half-page reproduction in colour of Chesley Bonestell's view of Saturn from one of her moons and says, "Tomorrow to fresh fields!"

Somewhat on the same theme is a recent advertisement by Samuel Fox & Company, makers of "Flying Fox" electric steels, which has appeared recently in the technical press. This is intended to depict the development of flight in three stages, but the spaceship has, unfortunately, the rows of portholes normally associated with science fiction.

The Anglo-Iranian Oil Co., too, in an advertisement explaining that they are currently prospecting for oil in all possible sites, show a picture of a spaceship leaving the Earth!

Obtaining foreign literature

We have recently received from Messrs. Lange, Maxwell and Springer, Ltd., 41-45, Neal Street, London, W.C.2, information concerning the extensive scheme they have set up for supplying foreign literature to scientists, students and libraries. The service includes: supplying of books and journals in all languages; photostats from any article in the British Museum or Science Museum Libraries; translation of articles into all languages and purchase and exchange of surplus publications.

Messrs. Lange, Maxwell and Springer have also sent us details of the UNESCO Book Coupon Scheme, which has been set up to facilitate the acquisition of publications between the members of UNESCO, and should be of great value to all those who have difficulty in obtaining foreign books and journals.

The Ernst Heinkel Prize

Professor Ernst Heinkel, the well-known aircraft designer, has presented a prize of DM 200 which will be awarded by the *Gesellschaft für Weltraumforschung* for the best research work on astronautics during 1951.

Second Award of Herman Oberth Medal

The second Hermann Oberth medal was presented to Dr. Eugen Sänger at the close of the G.f.W's fourth yearly congress at Stuttgart, on January 27. We congratulate Dr. Sänger on this honour, which he has done so much to deserve.

The "Ehrenbuch der Astronautik"

The first entries in the G.f.W's "Roll of Honour" (see B.I.S. *Journal*, 9, **138**, May, 1950) have now been announced. The six names so far entered are as follows: Professor Hermann Oberth, Baron von Pirquet, M. Robert Esnault-Pelterie, M. Alexandre Ananoff, G. E. Pendray—and, we are glad to note, our own P. E. Cleator.

North-West G.f.W

The Northwest German Society for Space Research held a meeting in Bremen on March 4, 1951, at which members and visitors were present from many towns in north and west Germany.

The chief business was the election of a new Council. The new President is Ing. Gerhard E. Janzon, of Dortmund; Vice-President is the physicist Burkhard Heim, of Göttingen, and the Secretary is Richard J. Rudat, of Friedrichstadt (Eider).

The above Council now also represents, by agreement, the successor of the old wartime German society: G.f.W (Berlin), which was founded in 1942 by Herr H. K. Kaiser, and of which the last President was Herr K. Ehricke, who is now in the U.S.A. This new association of German societies (which should not be confused with the *Stuttgart* G.f.W.) is to publish a monthly Journal, "Raketenflug," at present in duplicated form.

In the course of the programme of talks, which gave rise to stimulating discussions, Ing. R. Püllenberg, of Bremen, formerly in charge of the Hanover Rocket Airfield and collaborator at the former Rocket Research in Peenemünde, spoke on "Rockets Yesterday and Tomorrow." Ing. G. E. Janzon, former collaborator with Professor Hermann Oberth, brought forward in his lecture some critical reflections on the project of the Space Station and Ing. Karl Poggensee, well known as one of the earliest German rocket pioneers, discoursed on his rocket experiments with solid propellants.

Obituary

We very much regret to record the sudden death from heart failure, on April 8, of Mr. W. G. A. Perring. Mr. Perring was Director of the Royal Aircraft Establishment at Farnborough, which of course has its Rocket Propulsion Department at Westcott. He was a very prominent figure, who will be sorely missed, in all aspects of British aeronautical research and development, and will be particularly remembered by B.I.S. members for his R.Ae.S. paper on the V.2.

From the World's Press

In its December, 1950, issue, the American aviation monthly *Aero Digest* published a review of the aerodynamic characteristics of delta wings; this drew a most interesting letter from Dr. Alexander Lippisch, the famous German pioneer of this wing planform, which is printed in the February, 1951, number of the same periodical.

Dr. Lippisch (who is now, surprisingly, working for the Collins *Radio* Co. in Iowa) early on makes a disclaimer of being called a "rocketry fan" ("I did not participate in the formation of the V.f.R. . . . I was too old-fashioned and liked to enjoy life on our good old mother planet"). He goes on, however, to give some very interesting particulars of the first trials of gliders fitted with rockets, which were made by Stamer, Opel and Valier on airframes desined by Lippisch and his associates. In January, 1939, Lippisch and his team went to the Messerschmitt plant where, as "Special Dept. L," they produced the

Me.163A design which first flew in 1941. On October 2, 1941, Dittmar flew the Me.163A at over 1,000 km./hr. at 3,600 m.—a Mach No. of 0·85, which was a record for level flight at the time.

General Ernst Udet became enthusiastic and ordered work to start on the Me.163B military version. (This had a "hot" motor, burning C-stoff fuel with its hydrogen peroxide, or T-stoff; the earlier version fitted a "cold" motor, using T-stoff alone as a source of energy. Both types of power unit were, of course, made by Walterwerke of Kiel.) As we now know, the Me.163B came into operational use just before the end of the war; a still further improvement, the Me.263, was to have been built by Junkers, but never even reached the completed prototype stage.

Long before this first purely rocket-propelled fighter entered service in any of its forms, however, Dr. Lippisch says that "strained relations" with Professor Willi Messerschmitt caused him to leave the firm bearing the latter's name, and to join the Aeronautical Research Institute at Vienna. There Dr. Lippisch worked on further high-speed aircraft projects, with delta wings and either turbojet or ramjet propulsion; at the end of the war, in common with many other leading German scientists, he went to the United States.

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The feature "A Reporter at Large" in *The New Yorker* for April 21 was devoted to a long and extremely interesting interview with von Braun. Describing him as "exuberant rather than reflective" as a type, and as having the manner of a man "accustomed to being regarded as indispensable," the writer explains that he was introduced to him by an American Major as "That guy upstairs (who) wants to go to the Moon. That's his passion—interplanetary travel. Whether it will be war or peace on Earth comes after that for him." Later in the interview, however, von Braun showed that he had thought long and seriously about the latter question, and gave as his solution to the current problems plaguing mankind the need for a revival of true religious feeling. On the former question, he admitted that an article on an imaginary trip to the Moon had "filled me with a romantic urge" as a boy, and that he had been an interplanetary enthusiast ever since. Many interesting details of von Braun's career and personal life are given, including the fact that he has just completed a novel of science-fiction called "Mars Project," and that he was thrown into prison for a fortnight during the war. This was after he had offended Himmler by refusing to transfer the allegiance of Peenemunde from the Army to the Gestapo, which promptly accused him of plotting to fly his private plane to England with all the data on V.2. Although this charge was without foundation, it needed the personal influence of Hitler, enlisted by von Braun's Army chief (General Dornberger), to secure his release! Gen. Dornberger is stated to be with the Bell Aircraft Co. at the present time, while von Braun is "director of research and development projects at an Army Ordnance Guided Missile Center" in Alabama. B.I.S. members are urged to try and read this article for themselves, if they can find the copy of *The New Yorker* in question; one of the more entertaining sidelights is a description of a photograph of von Braun in diving dress,

preparing to descend to the Baltic seabed to inspect the remains of an experimental rocket!

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Time for May 21 carried a feature article on guided missiles, headlined "Birds of Mars." Guided missiles are always referred to as "birds" in the technical slang of this vigorous new American war industry; we assume "Mars" to have a military rather than an astronomical significance in this context, though perhaps some pun was intended. The article described the various missile types and guidance techniques in the inimitable *Time* style, which is capable of evoking so vividly in the laymen's mind the essentials of a complex technical subject, without (as a rule) losing appreciably in accuracy. "The head of one U.S. aircraft company" is quoted as believing that within ten years missiles will dominate air warfare, and that piloted aircraft will then be used only for transport. The article ends with an aphorism attributed to Einstein: "If World War III is fought with atom-armed missiles, then World War IV will be fought with clubs."

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Various American papers recently reported some remarks made to the Institute of Aeronautical Sciences by Major Charles Yeager, who was the first man to fly faster than sound (in the Bell X.1). He said that the U.S. Air Force would soon have available what he described as "space-flight" planes, capable of flying over 1,800 m.p.h. at over 100,000 feet altitude. Presumably the reference was to the Bell X.2 and Douglas X.3 rocket-propelled research aircraft, which are known to have been under construction for some time. Recent official releases (printed in *Time*, and also in various British newspapers) have stated they will be capable of performances of this order.

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Aviation Weekly for April 16 reports that Andrew Kalitinsky, until recently Chief Engineer of the American NEPA (Nuclear Energy for Propulsion of Aircraft) Project, has now been appointed as Manager of the Special Projects Department of the M. W. Kellogg Co., engaged on rocket power plants. The exploratory NEPA organisation, it has been widely reported elsewhere, has now been wound up in favour of placing actual design and development contracts for aircraft atomic power plants with G.E.C. and other firms. We imagine Kalitinsky's new job merely reflects the great importance of heat transfer knowledge in both nuclear reactors and rocket motors, though it would be exciting to put two and two together, to arrive at a total of not less than five and the conclusion that someone was now actively working on an atomic rocket.

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Aviation Age for March states that a Russian rocket range, 7,000 to 9,000 km. in length and starting north-west of Liegnitz in Poland, is scheduled for completion in August, 1951.

* * * *

When Cockroft and Walton first artificially "split the atom" in 1932, we well remember all the expert pronouncements about the impossibility of such a process ever releasing more energy than was needed to initiate it. At the time we felt a somewhat diffident scepticism, which was abundantly justified within 13 years. More recently, there have been a number of statements that it was extremely improbable that nuclear energy would ever (or at least for a very, very, long time) be released in a controlled manner by any process other than the now "conventional" one of fission. The whole Anglo-American-Canadian plan for the international control of atomic energy, which was submitted to UNO, seemed to be based on this thesis. In particular, it was said that the thermo-nuclear reactions of the light elements could be used to make the bigger-and-better hydrogen bomb, but would always be quite useless for any peaceful purpose of power generation. Once again, though admittedly from a background of sheer ignorance, we experienced that feeling of scepticism; things just don't develop that way in the world of science—the official view might be the logical and intellectually respectable one, but we suspected, Micawber-like, that something would turn up.

Now we wonder if it has not already done so. First there were the newspaper reports of Richter's work for President Peron in the Argentine. It was fashionable here and in America to sneer at this, and dismiss it as the attempt of a dictator and his puppet-scientist to obtain some sensational publicity and distract attention from other matters. Many contemporary considerations would support the likelihood of this explanation being correct, but we doubt whether it should be too lightly adopted. Although only a few expert commentators acknowledged it to be true, it is by no means impossible that Richter has achieved some laboratory reaction on a small scale which may have the most potent future significance on a larger practical scale—even though Peron, for his own purposes, may have greatly exaggerated the extent to which progress has advanced so far.

Now, in the *Daily Telegraph* for May 17, we read reports of apparently exactly similar work proceeding in "a small laboratory in the heart of London." "An unnamed British physicist," who "gained world fame for earlier work in nuclear physics," is alleged to have made "important discoveries that may open the way to the use of hydrogen as a nuclear fuel," although previously it was thought that "the hydrogen-helium 'fusion' reaction could have only war application." We hope this is true, and await further official statements with interest; it would have been a great temptation for any scientist hearing garbled press reports, of Richter's apparent work on similar lines to his own, to issue at least some tentative statement on his own progress. Priority in research claims means a great deal to such men; perhaps this is why we have received the news, so surprisingly at variance with what we had officially been led to expect.

* * * *

Air Chief Marshal Sir Alec Coryton (Chief Executive, Guided Weapons) and Sir Harry Garner (Chief Scientist), of the Ministry of Supply were on a

visit to the Australian rocket range early this year. Some interesting statements were made by Sir Alec in interviews with Australian journalists, emphasizing the importance of the Woomera facility and the fact that there was nowhere else in the Commonwealth where such tests could be carried out. He said "Our present research is on missiles designed to intercept attacking bombers rather than for purely aggressive uses. We can make missiles that will fly and we can guide them, but we still have a lot to find out about them. What we are really doing is replacing the human brain in flying machines—and that is no mean job."

* * * *

Most papers, towards the end of February, gave considerable publicity to a "space-ship" design prepared by Arthur V. St. Germain, described as senior test engineer for the Fairchild guided-missiles division of the U.S. Navy's experimental station at Point Mugu (California). The design sounded more plausible than some which get into print: a five-step assembly, 325 feet long and weighing 180 tons at take-off, it was to have a two-man crew, and achieve the lunar round trip.

* * * *

Dr. David Martyn, Chief Scientist of Australia's Radio Research Board, recently supplied the *Sydney Daily Telegraph* with information on which to base an article about space-flight: interplanetary travel was described as a certainty ("and perhaps not in the *very* distant future"), and the satellite rocket as a possibility "within the next few years."

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The *Evening News* reports that a pub named "The Flying Saucer" will soon be opened in Kent, and anticipates a crop of "flying saucer" stories originating there about closing time. They also speak of another house, to be called "The Jet and Whittle," which may open near Gloucester. If this sort of thing is going to become fashionable, we hereby serve notice that we intend to spend our own retirement as mine host of "The Fuel and Oxidiser."

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Mr. William Bergen, Vice-President and Chief Engineer of the Glenn Martin Co. (which built the Viking rocket) said in Philadelphia that he expected to see a crew-carrying spaceship become a reality within 10 or 15 years.

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The Astronomer Royal, Sir Harold Spencer Jones, lecturing last March at Cheltenham Town Hall, said that he believed "life in the Universe is comparable to some delicate flower, which is not to be found everywhere, but will come into existence only under a particular combination of circumstances." The evolution of life on other planets might conceivably have followed quite different lines from on Earth.

REVIEWS

Guns, Shells and Rockets

(By Major J. C. S. Hymans. 102 pp., index. Gale & Polden, Ltd., Aldershot. 3s. 6d. net.)

This is a first-rate little guide to the science of ballistics for anyone who, though having little scientific knowledge, wishes to understand the fundamentals of the subject. The author deals briefly, yet clearly, with all aspects of the subject, there being chapters on the internal and external ballistics of guns, fragmentation of shells, rockets and the experimental methods used to discover the performance of particular weapons.

Though his subject is highly mathematical, the author makes no demands upon the mathematical abilities of the reader, but presents a clear physical interpretation of each term, coefficient, or phenomenon he considers, and to make doubly sure an additional chapter is included at the end of the book for the benefit of those readers whose scientific ignorance is profound. This final chapter contains the usual definitions of the fundamental concepts of physics—pressure, energy, momentum, etc.

Members of our society will be interested in the chapter Major Hymans devotes to rockets. The commonly held belief that a rocket cannot operate in a vacuum is exploded and the principle by which a rocket propels itself is explained. The importance of the mass-ratio is stressed and multi-stage rockets are considered. The trend of German rocket research towards the end of the war is described and the ultimate rôle of the rocket as the solution to the problem of space travel is affirmed, and we can agree with the author's conclusion that "it is only a matter of time before sombody does manage to reach the moon, and when he does it will almost certainly be by rocket." D. F. L.

Rakieta Księżycowa

(Moon Rocket)

(By E. Białoborski, published by Państwowe Zakłady Wydawnictw Szkolnych (Government Text-Books Centre), Warsaw, 1950. Pp. 112, in Polish.)

We can now add one more title to an already long list of books on astronautics. This time it is a book published in Poland, and since this is the third Polish book on this subject we may shortly mention the preceding ones.

The first was a novel, published about 1903, *Na Srebrnym Globie* (On the Silver Globe), by J. Żuławski, and contained a fascinating description of lunar landscapes as seen by astronauts, who travel in an airtight car from Erathostenes to the North Pole. The writing is as suggestive and dramatic as Bonestell's pictures and, similarly, was checked for detail by astronomer friends of the author. From the technical point of view it is interesting to note that exploding mines were used to decelerate the projectile before landing.

The second book was a technical work: *Podróże Międzyplanetarne* (Interplanetary Travels), by F. Burdecki, and published about 1928. This was quite

a sound study based on works of Esnault-Pelterie, Oberth, Hohmann and others.

The present book, *Rakieta Księzycowa*, is an elementary text-book on rocket propulsion and space travel. It is written primarily for schoolboys, so the author introduces the subject by making use of the simplest mathematical derivation only. He sets himself a difficult task in presenting recent developments in rocket propulsion and includes several chapters on atomic energy.

Undoubtedly the book will provide much useful information for many readers, explaining how a rocket works and how we can realise the idea of interplanetary travel, but nevertheless, if we adopt a more critical attitude and examine the book closely we find it contains a number of errors and some rather misleading opinions.

The author considers that only atomic energy will provide the solution to space travel problems in the form of a rocket propelled by radiation pressure. As the nearest approach to this ideal he proposes a nuclear reaction-driven rocket with a direct ejection of the products of fission (v_e roughly 300,000 km./sec.). However he points out the difficulties of shielding and also concedes that "at present" this solution is not practical, because part of the energy is converted into heat, and dangerous to the rocket.

He rejects the possibility of the use of a propellant fluid heated by a nuclear fuel, since the mass ratio is there too high to be practical and, besides, it is against his principle of maximum exhaust velocity at a minimum mass.

The chemical fuel rocket, according to the author, belongs to the past. Any design of a chemical fuel rocket starts with the computation of mass ratio—with disastrous results. There is a mention of the existence of step rockets, but without proper explanation of their advantages.

The mass ratio, inherent to the late designs of chemical rockets, can also be calculated for a nuclear rocket; although it is not worthwhile for a trip to the Moon (please remember that $v_e \simeq 300{,}000$ km./sec.), but the position becomes serious if we consider an expedition to Proxima Centauri (a return trip in a lifetime). Moreover, modern atomic piles have an efficiency of 0·001, so it is too early to plan travels to the stars.

The author discusses the artificial satellite project. He sees it as a very useful laboratory, but seeks to show that no advantage can be gained by using it as a stepping stone for proper space flight, because more than the escape velocity is necessary to reach the orbit of the station and attain its orbital velocity. An unfortunate choice of the orbit for the space station (Earth's radius above Earth) is partly responsible for this opinion. The author, however, should be forgiven on this count for his delightful description of the difficulties of a rocket trying to make contact with the space station: "like a fly trying to alight on a rifle bullet."

The author very shortly reviews fuels and exhaust velocities; he defines the theoretical velocity as the velocity of *hot* gases escaping into a vacuum. The air pressure reduces it by a half, but in future true interplanetary flights in airless space the theoretical exhaust velocity is to be obtained!

In spite of these shortcomings and rather scant information on chemical fuel rockets, the book is useful; readers will be introduced to a new and fasci-

nating field of study; they will learn about the gravitational field and orbital motion, they will understand how a rocket can move in space and they will get a glimpse of new and unknown worlds. J. S. G.

Principles and Practice of Radar

(By H. E. Penrose and R. S. H. Boulding. 708 pp., 550 diagrams. 3rd Edition. George Newnes, Ltd., London, W.C.2, 1950. Price 42s.)

This book deals with the fundamentals of radar with emphasis on the application to marine radar. It is practically non-mathematical and is suitable for use as a text book by those engaged in servicing and maintaining radar, particularly marine radar equipment.

The subject matter is based to a large extent on several official publications, notably *Radar System Fundamentals* and *Radar Electronic Fundamentals* published by the U.S. government and the *Interservices Radar Manual*.

The third and latest edition contains some new material on particular installations, including some commercial shipborne models. Several misprints and mistakes which appeared in the second edition have been corrected, but not all, and a considerable number of non-standard terms and symbols are used which detract from the value of the book, particularly for teaching purposes. Furthermore, there is a lack of balance in some parts; for example, a whole chapter of over 50 pages is devoted to the Magnetron whilst the Klystron is dismissed in $2\frac{1}{2}$ pages.

Nevertheless, the book is at present the only one which deals with the fundamentals of radar at all thoroughly without the aid of mathematics and gives a good basis for further reading. D.J.C.

CORRESPONDENCE

SIR,

H. G. Wells

In H. G. Wells' "The First Men in the Moon," the hero describes the take-off from Earth thus: "I felt a pressure as of incalculable tons on the soles of my feet."

Shortly after the publication of this book, my father, who has a first-class honours degree in mathematics, calculated that the initial acceleration of the sphere would be less than g, and, consequently, the above description of the take-off would be grossly incorrect. He wrote to Wells, pointing this out and in due course he received a reply, which ran: "You are quite right about the pressure; but if you like that sort of thing, why did you overlook the shameless disregard of truth in the time that they took to get to the Moon?" or words to that effect.

It would therefore appear that Wells was well aware of the shortcomings of his antigravity project, and therefore, presumably, of the fundamental fallacies of his other literary creations, such as the space-gun in "Things to Come."

E. HOPE-JONES.

London, S.E.24.

RECENT AND FORTHCOMING MEETINGS

April 3, 1951 (Tuesday). "Interplanetary Travel," by G. V. E. Thompson, to the MeLeSco Society (The Superheater Co., Ltd.), at Film House, Wardour Street, London, W.1, at 6.30 p.m.

June 24, 1951 (Sunday). "Interplanetary Travel and Rocket Propulsion," by G. V. E. Thompson, to the National Adult School Union, at Friends Meeting House, Howard Street, Gt. Yarmouth, Norfolk, at 9.45 a.m.

July 5, 1951 (Thursday). "Interplanetary Flight," by L. J. Carter, to Springfield Young Conservatives, Church Institute, Wiseton Road, S.W.18, 8 p.m.

September 3-8, 1951. **Second International Congress on Astronautics,** at Caxton Hall, S.W.1. Working Sessions, September 3 and 4, Technical Sessions, September 6 and 7, **Public Lecture and Concluding Dinner on September 8.**

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